

Rikard Stankiewicz

**LEADERSHIP &
THE PERFORMANCE OF
RESEARCH GROUPS**

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RPI Research Policy Institute
University of Lund

Organization and the Effectiveness of Academic Research Groups

(summary of a doctoral dissertation)

Rikard Stankiewicz

Lund, 1980

ORGANIZATION AND THE EFFECTIVENESS OF ACADEMIC RESEARCH GROUPS

av

Rikard Stankiewicz

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Abstract A large majority of the Swedish academic scientists in natural science and technology work in research groups. The present study, which constitutes a part of a larger international project sponsored and coordinated by Unesco, examines the hypothesis according to which research in groups fosters intellectual synergy. Synergy is defined a process whereby the group members reinforce each other's productivity and creativity. The test of the hypothesis is conducted by examining the relationship between the size of groups and their per capita performance. The relationship is found to be positive; however, its form and strength vary depending on several intervening factors. Particularly important among the latter are: the intellectual coherence of the groups' research programs, their social and psychological cohesion, and the nature of leadership. The synergistic effects are found to occur frequently in the groups headed by scientists with tenure but to be largely absent in the groups led by junior scientists. These differences are interpreted as the results of the changes in the leader-roles which occur when the scientists occupying them move from one stage of their scientific career to another. The great importance attached by the junior scientists to their personal performance, as opposed to the emphasis on the effectiveness of the groups as wholes, is seen as one of the main factors affecting negatively their behavior as group leaders. A close connection is thus established between the socio-psychological and the institutional analysis of research processes.			
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Organization and the Effectiveness of Academic Research Groups

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Organization and the Effectiveness of Academic Research Groups

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I. INTRODUCTION

The study which is summarized here deals with the organization and effectiveness of Swedish academic research groups in the fields of natural science and technology. I have presented its detailed results in four publications:

- I. Research Groups and the Academic Research Organization, in Sociologisk Forskning, 2, 1976
- II. The size and age of Swedish academic research groups and their scientific performance, in Scientific productivity. The effectiveness of research groups in six countries, ed. Frank M Andrews, Cambridge University Press & Unesco, 1979
- III. The effects of leadership on the relationship between the size of research groups and their scientific performance, in R&D Management, vol 9, Special Issue, 1979
- IV. Leadership & the performance of research groups, RPI, Lund, 1980

The study is a part of a larger international project (the International Comparative Study on the Organization and Performance of Research Units) initiated and coordinated by Unesco. The project which has been carried out in Austria, Belgium, Finland, Hungary, Poland and Sweden, involved a questionnaire survey of over 1200 research groups in a variety of fields and institutional environments. Data has been obtained concerning a wide range of organizational, socio-psychological, institutional and intellectual characteristics of the groups. In addition, information was acquired concerning the quantity and quality of the groups' scientific output. (Further details about the organization and execution of the International Study can be Found in Appendix A of report IV.)

The analysis of the data generated in the course of the International Study has been carried out by independent research

teams from the six participating countries and from Unesco's Science Policy Division. The range of topics covered in those analyses is described in Appendix A of report IV. Some of the analyses were done on the entire international data set (1222 groups), while others were based on the national subsamples only. The study summarized here belongs to the latter category.

The Swedish subsample consisted of 172 randomly selected research groups from the faculties of natural science and technology at the universities and technical highschoools. (The details concerning the sampling procedures are given in Appendix B in report IV.) The data was obtained using the standard questionnaires of the International Study supplemented with a number of additional questions reflecting the special interest of the Swedish team.

The Swedish data was analysed at two levels. Göran Jense focused on the variables pertaining to the individual group members (see G Jense, The Academic Marketplace, Lund, 1979) while R Stankiewicz concentrated on the group-level processes.

II. THE MAIN HYPOTHESES OF THE STUDY

The general theme of the analysis summarized below can be formulated as follows:

Scientific research is an intensely social activity. The productivity and creativity in science is, to a large extent, the function of mutual reinforcements (synergy) resulting from intellectual interactions among researchers. The level of synergy in the scientific communities depends on various cognitive, organizational and institutional factors. Especially important as the means of promoting intellectual synergy in science is the creation and effective management of research groups.

From the above stated general premises it follows, among other things, that:

- group based research should be expected to constitute the dominant pattern of scientific organization, and that, given appropriate management,
- there should be a positive relationship between the size of groups and their per capita performance; the reason for this is that the potential number of interactions (and thus mutual reinforcements) in groups increases exponentially with their size.

III. THE PREVALENCE OF RESEARCH GROUP ORGANIZATION IN THE SWEDISH ACADEMIC NATURAL SCIENCE AND TECHNOLOGY

For the purposes of our study a research group has been defined as "a group of scientists (at least two) working under common intellectual leadership in a well defined research speciality. The members of the group engage in continuous or periodic collaboration. The leader is an active researcher in the group. A scientist may belong to more than one research group. The members of the group may be recruited from two or more formal units/organizations".

The above definition, which has been worked out in the course of intensive pilot studies, was used to identify groups at the faculties of natural science and technology at the Swedish universities and technical highschools. The procedures used in that survey are described in report I. The main facts which emerge from the survey are:

- Group based research constitutes the dominant mode of organization in the surveyed fields. About 75 % of the scientists at the natural science faculties and over 60 % of those at the faculties of technology belonged to one or more research groups.
- The propensity to form research groups varies with research fields. It is very high in the so called "hard" natural sciences (physics, chemistry, and molecular biology) where 90 % of scientists were re-

ported to be group members. The lowest propensity was found in the traditional engineering fields, such as mechanical engineering and architecture, where the corresponding percentages were 26 resp. 17.

The above results contradict the widely held belief that group organization is characteristic of the applied rather than fundamental sciences. They square well, however, with the synergy hypothesis outlined in the preceding section. It can be argued that, in the theoretically well integrated fields such as physics and chemistry, research problems form closely interconnected clusters. The solution of one problem in a cluster will often have immediate consequences for the solubility or definition of the others. It means that the likelihood of synergic effects in these fields is greater than in the theoretically less integrated ones. This seems to provide a highly plausible explanation of the observed differences in the propensities to form research groups in the surveyed fields of science.

IV. THE SIZE OF GROUPS AND THEIR SCIENTIFIC PERFORMANCE

The general properties of the studied groups are presented in report IV. The relationship between the size of groups and their performance is analysed in report II.

As pointed out earlier the synergic nature of research in groups implies the existence of a positive relationship between the size of groups and their per capita performance.

The performance of the groups was measured in terms of their output of papers per group member and the amount of "Scientific Recognition" which the groups received from other scientists in their fields. The ways in which these measures were developed and tested are outlined in Appendix C of report IV. Group Size was defined as the average number of scientists in the group during the three years prior to our study. In all the analyses involving Group Size, the effects of Group Age were controlled for.

The main conclusions of the analysis presented in report II are:

- As predicted, there exists a tendency towards an overall positive relationship between the size of groups and their per capita performance; however,
- the strength and form of that relationship varies depending on a number of intervening variables; thus
- the positive relationship between Group Size and Scientific Recognition is conditional on the high level of coherence of the groups' research programmes;
- the relationship is also influenced by the degree of social cohesion in the groups: in the groups with low cohesion, the relationship is strongly curvilinear with the decline in Recognition occurring when the groups grow larger than 6-7 scientists;
- there is a strong interaction between Group Size and the characteristics of the leaders; the groups headed by scientists with 15 or more years of R&D experience exhibited a strong positive relationship between size and performance per capita, while those headed by junior leaders exhibited weak or even negative relationship.

While the connection between group cohesion (intellectual and socio-psychological) and synergy was largely self-explanatory, the interpretation of the effects of leadership proved to be a more complex task.

V. LEADERSHIP AND THE PERFORMANCE OF RESEARCH GROUPS

The effects of leadership on the performance of the groups are examined in detail in reports III and IV.

In order to understand the role played by the leaders it was necessary to distinguish between three kinds of effects which they could be expected to have on the performance of their groups: 1) the additive effects which reflected the leaders' direct personal contributions to the outputs of their groups; 2) the reinforcing effects which were due to the leaders' influence on the effectiveness of other individual group members, and 3) the synergistic effects proper which were due to leaders' ability to promote mutual reinforcements among the group members. Several hypotheses were presented linking each of these effects to a set of leader characteristics. The most important of these characteristics were: research experience, time devoted to the groups, and employment situation. They were said to reflect the leader's position in the academic career which was subdivided into three broad chronological stages: 1) Apprenticeship - the pre PhD stage, 2) Limbo - the "post-doc" stage, and 3) Tenure.

The examination of the data led to the following conclusions:

- The additive effects appeared to be related chiefly to the amount of time which the leaders devoted to work in the groups as well as their position in the academic system. The influence of the second of these factors was interpreted as being the result of the pressures to demonstrate individual productivity and competence which differ from one stage of the scientific career to another.
- The reinforcing effects were more difficult to pinpoint with any degree of accuracy. They seemed to be related chiefly to the time devoted by the leaders to work in the groups and, with less certainty, to their research experience.
- The synergistic effects - which constituted the main focus of the analysis - were found to be largely unrelated to the time which the leaders spent with their groups. Instead they appeared to vary with the

research experience of the leaders and their academic positions; thus

- the groups headed by professors and lecturers (Tenure stage of the career) showed strong synergistic effects;
- the groups headed by junior scientists (Apprenticeship stage) showed no evidence of synergy; and
- the groups headed by docents and research fellows (Limbo stage) showed signs of negative synergy.

In order to elucidate the link between the academic position of the leaders and group synergy it was necessary to examine the effects of the leaders' status on various aspects of group integration: the pattern of communication and collaboration in the groups, the members' perceptions of group cohesiveness, and the pattern of "division of labor" in the groups.

Contrary to expectation neither the pattern of communication/collaboration in the groups nor the members' perceptions of the group cohesion seemed to be significantly affected by the institutional characteristics of the leaders. However, the sociometric analysis of the group structures shed useful light on the general role played by the leaders.

- The leaders emerged as the "spindles" holding the groups together. This was crucial since the level of direct collaboration among the ordinary group members tended to be relatively modest. The data suggest that it is not possible to achieve a high level of group integration simply by relying on the spontaneous gregariousness of scientists. What is required instead is a mediating agent in the form of an active group leader.

Further analysis of the data indicated that the degree of success in the performance of such integrative functions depended

on the initial coherence of the groups' research programmes and the motivations and attitudes of the leaders.

Concerning the latter, it proved important to distinguish between the socio-emotional and the intellectual aspects of the relations between the leaders and the non-leaders. The socio-emotional aspect was related to the psychological support which the leaders gave the group members. It is natural that in an activity as unstructured and insecure as scientific research, the sense of getting or not getting psychological support should strongly influence the members perception of group cohesion. However, this socio-emotional aspect of leadership, while possibly affecting the reinforcement which the individual group members received from the leaders, was not related in a clear-cut manner to group synergy. The latter was found instead to be linked to the intellectual aspect of leadership as reflected in the pattern of "division of labor" in the groups.

The analysis of work processes in the groups has led to the identification of three main patterns of technical role differentiation. Significantly these patterns corresponded to the three main relationships between the size and performance of the groups.

- The first pattern, which is characteristic for the professor- and lecturer-groups, reflects a situation in which the leader, while firmly in charge of the overall direction of the group's work, must depend on the group members for the performance of such time-consuming functions as data collecting and -- to a lesser degree -- the analysis. As far as the other functions are concerned, he does not differ much from the rest of the group. It appears that this dominance-dependance situation, combined with the fact that, because of his position, the leader does not have to work under extreme competitive career pressures, creates favorable conditions for his/her functioning as the catalyst of the group process leading to synergy.

- The characteristic pattern for the docent and research fellow groups is quite different. Such groups prove to be extremely leader-centered. Docents and research fellows tend to dominate almost all research functions in their groups. The overall level of involvement of the non-leaders is here lower than it is in the groups headed by professors. Thus it seems that, in so far as the leaders of such groups play integrative roles they do so at the cost of restricting the scope of activities of their fellow researchers. Such hyperactive, and perhaps egocentric, leaders achieve high levels of individual productivity, but find it difficult to maintain similar levels of performance in the groups -- this shows with increasing clarity as the groups grow large.
- In the pattern which is characteristic for the junior scientist-groups, the role differentiation is hardly visible. Evidently, the differences in status among the members are too small for the leadership structure to emerge in a real, rather than purely formal, sense. This absence of leadership accounts for the lack of synergy in the groups which behave as if they were simple aggregates of scientists.

VI. FINAL REMARKS

The starting point of the analysis summarized above was the hypothesis that scientific research constitutes a synergistic activity in which the interacting individuals reinforce each other's creativity and productivity. Research groups were viewed as particularly important means of achieving high levels of intellectual synergy. The empirical findings presented above confirmed these hypotheses. Thus, we saw that - at least as far as the academic natural science and technology are concerned - working in groups was the dominant pattern of organization. The prevalence of this pattern seemed to reflect primarily the intrinsic needs of specific research fields.

A fairly high level of intellectual coherence in a research activity appeared to be necessary for the development of synergy. Another crucial condition for the occurrence of synergy was the presence of appropriate group leadership. The analysis indicated further that there existed an important connection between the behavior of leaders and their positions in the academic system - a connection which should be taken into account when changes in the university organization (particularly its career system) are planned.

Note: for bibliography, see reports II and IV.

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I. INTRODUCTION

The present report deals with the effects of leadership on the performance of academic research groups.^{1/} It follows an earlier study (Stankiewicz, 1979) which was focused on the relationship between size of groups and their effectiveness. That relationship was found to vary depending on the characteristics of the group leaders. It was established, among other things, that the per capita output of the studied groups tended to increase with their size when the groups were headed by senior scientists (with 15 or more years research experience) and to decrease when they were headed by junior scientists. The aim of this paper is to explore further these effects and to test several hypotheses that might explain them.

The contents of the paper are as follows:

Chapter II presents the empirical and theoretical foundations of the subsequent analysis. I start by reviewing the main features of the studied groups. This is followed by an outline of what may be called the "synergistic" hypothesis. According to this hypothesis, the effectiveness of research groups depends primarily on their ability to foster intellectual interaction among their members. Some earlier empirical tests of the hypothesis are presented. The importance of the characteristics and behavior of the leaders as promoters of group synergy is then discussed, and a set of hypotheses are given about the nature of the leaders' impact on the group performance. The most important of these hypotheses argues that a scientist's ability to promote group synergy and hence to be effective as a leader is strongly influenced by his/her position in the academic system.

Chapter III examines in detail the relationship between the performance of the groups and the leaders' positions in the academic system. The results are shown to confirm the hypotheses formulated in chapter II.

Chapter IV is concerned with elaboration of the empirical findings reported in chapter III. It seeks to identify the specific

mechanisms by which the leaders promote/inhibit group synergy. For this purpose the influence of the leaders on the organization of work and social integration of the groups is examined. Among other things, it is shown that there exists a correlation between the occurrence of "synergistic effects" and the pattern of "division of labor" between the leaders and non-leaders. This pattern reflects, in turn, the leaders' position in the academic system.

Chapter V discusses briefly the limitations inherent in the foregoing analysis and suggests possible extensions of it.

Chapter VI contains the final summary and discussion of the results.

The paper ends with three technical appendices dealing with the general background of the study, the sampling procedures used and the choice and construction of the performance measures.

II. LEADERSHIP AND THE PERFORMANCE OF ACADEMIC RESEARCH GROUPS: THE PROBLEM AND ITS BACKGROUND

It is widely recognized that good leadership is one of the pre-conditions of effectiveness of "small groups". (For a review of literature, see Hare, 1976). There is, however, no single coherent theory explaining why this should be so. The absence of general explanatory models depends, to a large extent, on the enormous heterogeneity of "small groups". A production team in a factory requires a very different type of leader than, say, a street-corner gang. Both these groups will in turn differ from groups of persons solving semantic puzzles in a psychologist's laboratory. It is thus extremely difficult, if not futile, to try to develop any theory of leadership without first making clear the exact nature of the groups to which it is supposed to apply.

For this reason it is useful to begin this paper with a short characterization of the groups with which it is concerned.

1. The data

1.1 Research groups: definition, population, and sample

The present paper is based on data collected from a representative sample of nearly 200 Swedish academic research groups in the natural and technological sciences. The survey in the course of which this data was obtained constituted a part of a larger international study sponsored and coordinated by UNESCO (for details concerning that study see Appendix A).

For the purpose of the study, a research group is defined as "a group of scientists (at least two) working under common intellectual leadership in a well defined research speciality. The members of the group engaged in continuous or periodic collaboration. The leader of the group is an active researcher in the group. A scientist may belong to more than one research group. The members of a group may be recruited from two or more formal units/organizations."

This definition is a result of an intensive study of the structure of academic departments in the natural sciences and technology. The detailed results of that study have been presented in an earlier paper (Stankiewicz, 1976).

The above definition was used to identify the population of research groups at the Swedish departments of natural science and technology. A random sample of 172 such groups was then subjected to a more intensive investigation. The details of the sampling procedure are given in Appendix B. Table 1 indicates the composition of the sample.

Table 1. The composition of the sample

<u>Field Faculty</u>	<u>Formal sciences</u>	<u>Physics</u>	<u>Che- mistry</u>	<u>Biology</u>	<u>Earth & Space</u>	<u>Engineer- ing</u>	<u>All</u>
Natural sc. faculties	8	19	22	43	9	--	101
Technology faculties	6	18	11	--	3	33	71
All	14	37	33	43	12	33	172

The properties of the groups included in the sample were analysed in several earlier reports and publications. Some of the analyses focused on the groups as such, while others centered on the individual group members. A general presentation of the data on the group level will be found in Stankiewicz (1976) and Jense and Stankiewicz (1976). Further aspects of group organization are presented in Stankiewicz (1979). Jense (1979) conducted a very broad analysis of the data on the individual level. Comparisons of the Swedish sample with those from the other countries that participated in the UNESCO project can be made by consulting Andrews, ed. (1979).

In what follows I shall limit myself to a very general presentation of the main features of the studied groups. Special

attention will be paid to: the place which the groups occupy in the academic system, their "demographic" properties, their research activities, and their interactions with the scientific environments.

1.2 The place of the studied groups in the academic system

The groups studied here may be said to constitute the primary units of research organization in the fields investigated. Indeed, a large majority of the academic researchers in natural science and technology at the Swedish universities were found to belong to one or more research groups (Stankiewicz, 1976). In fields such as physics, chemistry, and molecular biology about 90 percent of scientists worked in groups. Furthermore the fraction of research activity which the individual scientists conducted outside the groups tended to be marginal.

The studied research groups tended to possess a considerable degree of autonomy in relation to their departments. Thus, not less than 25% of the groups regarded their budgets as completely distinct from those of their departments, and another 47% claimed at least partial budgetary autonomy. Furthermore, almost 40% of the groups claimed that their departments had no influence on the direction of their research, while an additional 20-30% viewed such influence as purely marginal.

Although as a rule the members of a group were recruited from a single department, not less than 15% of the groups consisted of scientists coming from two or more departments.

1.3 The "demographic" properties of the groups

The groups included in our sample varied in size from 2 to 30 members -- with the average at 5.6. They consisted of four categories of personnel: the leaders, other scientists with supervisory functions, scientists without supervisory functions, and technical personnel. Table 2 gives the distribution of the

groups by the number of personnel in different categories.

Relatively few groups (24%) contained all four personnel categories. Nearly half of the groups contained no technicians and only one third had two supervisory levels, i.e. the leader and one more supervisory scientist. The presence of extra supervisors seemed to depend solely on the group size. The groups in technology included more often technical personnel than did the groups in other fields.

Table 2 The size and composition of the groups. Percentage of groups with a given number of members of a specific kind

Type of members	Number of members								All	Mean
	0	1-2	3-4	5-6	7-8	9-10	11-12	13-		
All members	-	12%	37%	17%	12%	9%	6%	7%	100%	5.6
Scientists (incl. leader)	-	19%	42%	19%	7%	5%	5%	3%	100%	4.8
Supervisors (excl. leader)	67%	22%	11%	-	-	-	-	-	100%	0.7
Technicians & support staff	48%	35%	10%	3%	-	1%	0,5%	0,5%	100%	1.3

The groups tended to grow during the first 8-9 years of their existence after which their size tended to stabilize. The field and faculty of the groups were largely unrelated to their size, although there was a tendency for the mathematicians and technologists to form smaller groups than the natural scientists.

The composition of the groups was analysed in great detail by Jense (1979). As could be expected the group members (non-leaders) were predominantly young scientists most of whom worked on their PhD dissertations. However, this did not mean that the groups were mere devices for effective supervision of doctoral students. More than one fourth of the members (non-leaders) held a degree above the basic one. Furthermore not

all the leaders could be regarded as "established" or senior scientists - roughly one fifth of them lacked the PhD degree. The characteristics of the leaders will be examined in greater detail in a later part of the paper.

1.4 The research activities of the groups

The groups were highly autonomous in determining their research objectives. Table 3 gives the average percentage of influence over the groups' research programmes attributed by the group leaders to various categories of decision-makers (including the group members themselves). The general pattern indicated in the table holds across all the research fields within each faculty.

Table 3 The average % of influence to each of the five factors by faculty

Faculty	Science policy bodies	Univer- sities	Depart- ments	The group itself	Others
Nat.science fac.	7.0	0.7	13.1	67.5	5.3
Technical fac.	14.4	1.1	14.5	64.3	7.2
Total population	10.1	0.9	16.6	66.1	6.4

Were the groups studied by us equivalent to "project-teams"? No. Only about one third of the groups were engaged in a single project; 40% worked on two or three projects, and the remainder on four or more projects. The number of projects was related in a linear fashion to the group size. The proportion between the number of scientists and the number of projects tended to be 2:1.

In most fields the estimated duration of a project was around six years with the exception of formal sciences and engineering where it was 3 and 4 years respectively. Chemists and bio-

logists tended to engage in particularly long-lasting projects. More than 40% of the projects in these areas had an estimated duration of 8 years or more.

The apparent plurality of projects in the groups leads to the question as to whether the groups really constitute meaningful organizational entities. Here it must be kept in mind that the number of projects in a group does not represent the only, nor the best, measure of its intellectual integration. When asked to estimate the coherence of their groups' research programme, a very large majority of scientists described it as high or very high, while only 20% viewed it as low. In fact the coherence of the research programme was only moderately correlated with the number of projects ($r = -.32$). Clearly, even the groups working on multiple projects could possess a high degree of intellectual cohesiveness provided their projects were thematically interrelated.

The thematic cohesiveness of research conducted by the groups was largely a function of the influence exercised by the group leader. This is quite natural considering the fact that practically all the groups have grown up around their leaders - as illustrated by the fact that there is an almost perfect correlation between the age of the groups and the number of years they were headed by their current leaders. Indeed, the leader may be regarded as the "original member" around whom the group gradually assembles.

Table 4 gives the rankings by the groups' leaders and non-leaders of 17 factors which may be expected to influence the direction of the work of individual group members. The two sets of rankings are closely correlated - with one exception, however. While the leaders rated "Own R&D Experience" (in- or outside the group) very highly (rank 4 and 3), the non-leaders treated it as rather insignificant (rank 11 and 15). Moreover, in the case of non-leaders, the "Leader's Influence" (decision & support) which ranks as 3 and 4 appears to function as a sort of substitute for "Own R&D Experience".

Table 4 Rank-ordering of the factors influencing the individual scientists' choice of research problems

Influencing factors	Ranking by the	
	leaders	non leaders
Education	1	1
Personal interest	2	2
Own R&D experience <u>outside</u> the group	3	15
Own R&D experience <u>inside</u> the group	4	11
Leader's support	-	3
Leader's decision	-	4
Theoretical importance	5	5
Availability of a research grant	6	8
Group's support	7	6
Practical importance	8	10
Availability om time for research	9	7
Availability of apparatus	10	9
Contacts with scientists outside the group	11	12
Academic merit	12	13
Prospect of quick results	13	14
Financier's wishes	14	16

This juxtaposition of the rankings suggests three conclusions: (1) research grows out of research, (2) the research groups constitute devices through which new generations of scientists are plugged into this process and (3) the group leaders function as the links between the younger scientists and the living research traditions.

The centrality of the leader's position is evident also when we examine the pattern of collaboration in the groups. The leaders were found to collaborate with nearly all other group members, while the non-leaders had rarely more than two collaborators in the group. We shall examine these aspects of group organization in greater detail in a later part of this paper.

1.4 The external exchange of the groups

Most of the groups were involved in collaboration with other groups or individuals. In fact not less than 62% of the groups reported being involved in at least one collaborative project with some external scientists. The median number of external collaborators reported by the group leaders was 3 and by non-leaders 1. On the strength of these figures one could conclude that groups lack clear boundaries, i.e. that they merge into one another through the intricate network of links. That however is not the case. Most of the external exchanges in which the groups and their members engaged were relatively superficial. Thus, only a few groups conducted more than 15% of their R&D activities in collaboration with other groups and the median figure concerning the amount of time devoted by the members to work outside the group proper was 5 percent.

2. Group organization and the research process: the synergy hypothesis

2.1 The synergy hypothesis

Academic science has the reputation of being a highly indivi-

dualistic activity. Why then are research groups -- such as those described above -- formed? There are many alternative answers to this question each of which has some validity in specific cases. One answer could be that the groups are formed because the development towards "big science" with the emphasis on expensive heavy equipment, makes them necessary (Weinberg, 1970; Wilson, 1970). Another answer might be that the groups are formed by the prestigious or otherwise powerful scientists to exploit more effectively younger scientists (Hagstrom, 1965 and 1967). Still another possibility is that the groups are formed to solve the thorny problems of supervision of younger scientists by the seniors. And so on.

I will not debate here the relative merits of the above hypotheses. Instead I will propose another one which complements them: research groups are formed simply because they offer competitive advantage to their members -- both senior and junior. The magnitude of this advantage will differ between research fields explaining the relative prevalence of group organization in them (see Stankiewicz, 1976, and Hagstrom, 1967).

Why should work in research groups offer scientists advantages? Is the solving of scientific problems comparable to building bridges or performing a complex military operation, requiring precise definition of objectives, rigorous planning, and careful coordination of many individuals? Rarely.

The advantage of research groups, I would suggest, rests on the fact that such groups create the socio-psychological environment which is conducive for individual creativity and productivity. Scientific research is indeed a highly individual activity requiring freedom from rigid formal coordination (Pelz & Andrews, 1976). However, it is also an activity that is greatly stimulated by interactions (communication/collaboration) among the scientists (ibid.). Such interactions enhance the intellectual synergy, i.e. the process by which the scientists reinforce each other's creative potential and work capacity. The specific aspects of this process include such things as the cross-fertilization of ideas, complementarity of skills,

coordination of work, communication of tacit knowledge, mutual criticism, error detection, psychological support and many others.

Forming research groups may be regarded as the means for achieving a high level of interaction among scientists and, thus, promoting the intellectual synergy. Since such synergy should increase with the number of scientists involved one would expect a positive correlation between the size of research groups and their scientific performance. This hypothesis was tested by, among others, Shockley (1957), Wallmark et al (1966, 1973) and Blume and Sinclair (1973) who reported positive results.

In an earlier paper (Stankiewicz, 1979) I reported an analysis that tried to test the synergy hypothesis using the data from the groups described in the preceding section. The results of the analysis are summarized below.

2.2 The relationship between the size of research groups and their performance

The performance of the groups was measured in terms of their output of published papers (a quantitative variable) and the amount of "Scientific Recognition" they received from other researchers in their fields (a qualitative perceptual variable).^{2/} Given the fact that the groups were concerned with basic research rather than technical development work the above measures of performance seemed appropriate. The ways in which these measures were developed and tested are outlined in Appendix C.

The main concern of the analysis was to assess the impact of the group size on the "per capita" effectiveness of the groups. For this reason we calculated the Output per Scientist, by dividing the total output of published papers by the number of scientists in the group. To moderate its skewness, the new variable was then bracketed according to quintiles.

The index of Scientific Recognition, which was based on ordinal ratings, could not be transformed into a "per capita" measure. This makes the interpretation of the results involving that index somewhat more complicated.^{3/}

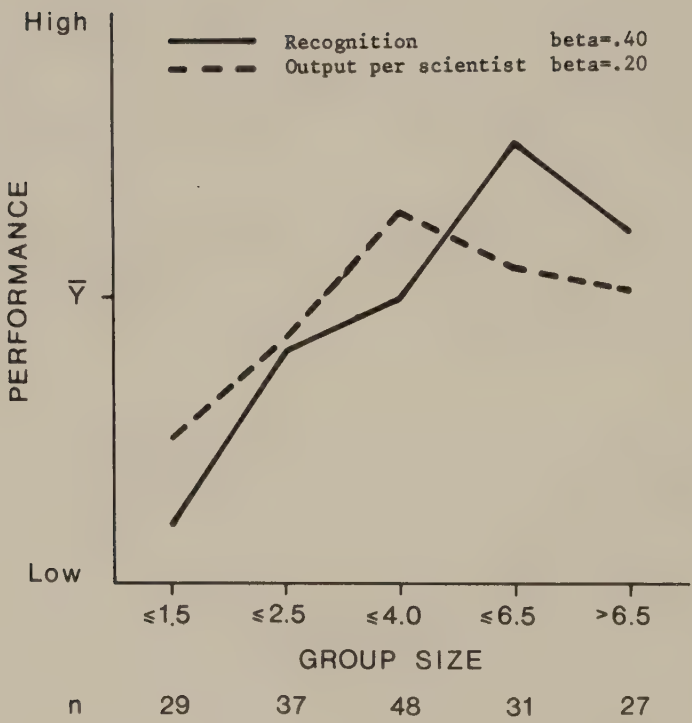
Group Size was defined as the average number of scientists in the group during the three years prior to our study. This index may appear a little odd since it allows for groups with fractional membership; for example: 1.3 members in the case of a group which existed for only two years during which it had two members. However the index proved to be the best measure of the group's manpower, primarily because it was insensitive to comparatively recent fluctuations in the group size. The index was based solely on the number of professional scientists, since the preliminary analysis indicated that the number of technicians had no independent effect on group performance and could therefore be disregarded.

The analysis was conducted using ANOVA and Multiple Classification Analysis which permit the study of curvilinear relationships. Since the Group Size is correlated with the Group Age the effects of the latter were controlled throughout the entire analysis reported below.

The results of the first crude analysis are presented in Chart 1. It can be seen that there exists a fairly strong relationship between Group Size and Scientific Recognition. The relationship remained statistically significant even when the effects of the groups' output of papers were controlled. This suggested that not only the quantity but also the quality of work was affected by the groups' size. The relationship is curvilinear with the optimum corresponding to the average size of 6-7 scientists. This tendency could be interpreted in terms of well known effect: the pattern of group integration tends to undergo significant change when groups grow larger than 5-7 members (Berelson & Steiner, 1964).

The examination of the relationship between Group Size and the output per scientists was somewhat disappointing. The expected

Chart 1: Group Size and Performance, controlling for Group Age



relation did appear but was quite weak and again curvilinear.

The next step in the analysis was to examine the stability of the above relationships. Starting from the synergy-hypothesis it seemed important to check the effects on the correlations between Group Size and Performance of various factors expressing or affecting the levels of integration in the groups.

Three aspects of integration seemed particularly pertinent:

1. The degree of coherence of the group's research programme (as perceived by group members)^{4/}
2. The social integration of the group as measured by the members' identification with it, and
3. The characteristics of leadership.

All of these variables were found to interact with group size. As could have been expected, the relationship between Group Size and Scientific Recognition was strengthened in the groups characterized by high coherence of the research programme ($\beta = .59$) and almost disappeared in the groups characterized by low coherence.

The effects of social integration were less dramatic but nevertheless significant. The curvilinearity of the relationship between Group Size and Scientific Recognition tended to weaken considerably in the groups characterized by high social cohesion and increase markedly in the groups with low cohesion.

Significant and interesting as these interactions may be, they occurred only in relation to the index of Scientific Recognition. The relationship between Group Size and the output per scientist seemed to be quite unaffected by the levels of intellectual and social cohesiveness. However, the situation proved different when we turned to the examination of the interactions between Group Size and the properties of leadership.

Two such properties were singled out: the amount of time the leader spent working in the group and his/her research experi-

Chart 2: Group Size and Output per Scientist, given the leader's Time in the Group and controlling for Group Age

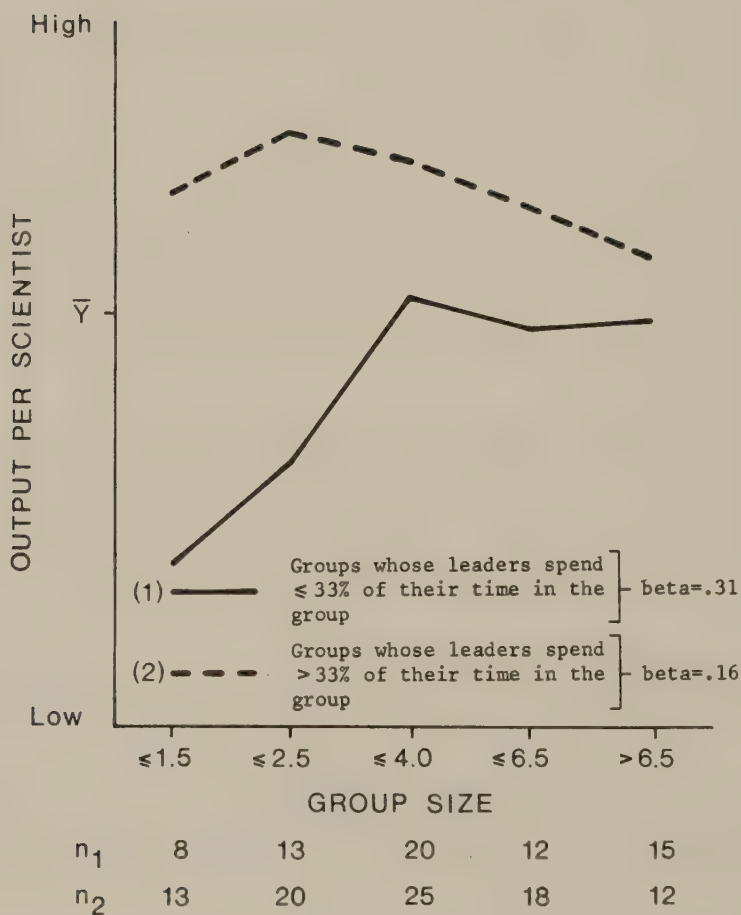
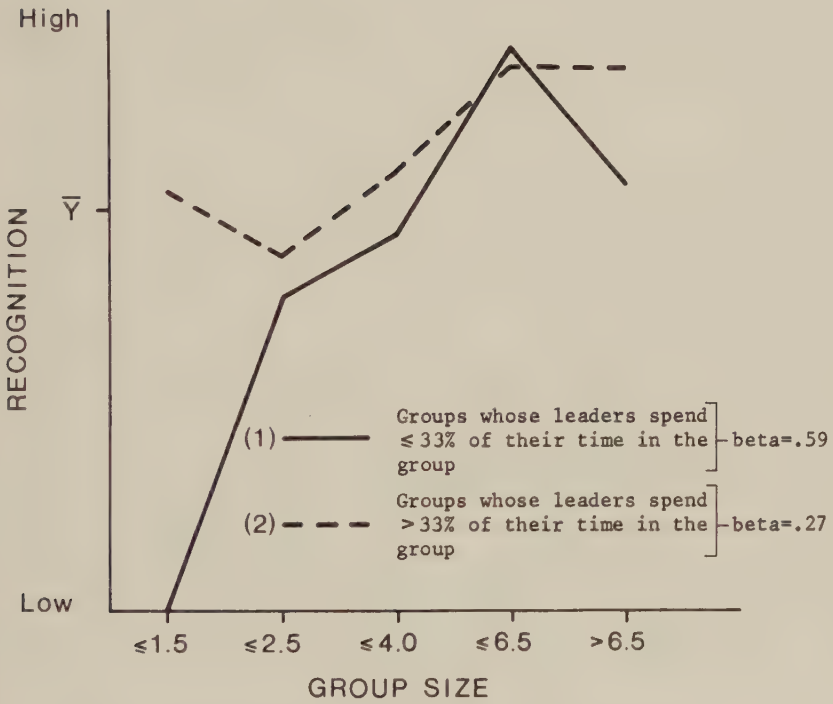


Chart 3: Group Size and Recognition, given two levels of the leader's Involvement (Time in the Group) and controlling for Group Age



n_1	8	13	20	12	15
n_2	13	20	25	18	12

ence. The reasons for choosing these characteristics were rather obvious. Leaders who devoted much time to work in their groups were expected to be better able to act as integrating factors. I also felt that long research experience would be conducive for good intellectual management of the groups.

The results obtained were interesting but not quite straightforward. In the first place it emerged that while the Output per Scientist and Recognition of the groups led by highly involved leaders was generally higher than that of the groups headed by the leaders with low involvement, this difference was strong only in the case of small groups (see charts 2 and 3). This is contrary to what we would expect if the leader's involvement did in fact promote group synergy. If the synergy hypothesis is right the pay-offs of the leaders' involvement should be highest in large groups rather than in small ones.

The interactions between group size and the leader's research experience were both less ambiguous and stronger. As chart 4 indicates, there exists a strong positive correlation between Group Size and Output per Scientist in the groups headed by scientists with more than 14 years of research experience, and a less pronounced negative correlation in the groups headed by less experienced leaders. The differences are the strongest in the case of very small groups. On the whole it would seem that the small groups headed by junior scientists are doing approximately as well as the large groups headed by the senior scientists. This result is consistent with what we observe in chart 5. Here we note a very strong relationship between Recognition and Size in the groups headed by the more experienced scientists and only a weak tendency towards correlation in the groups headed by the less experienced leaders.

This brings us to the main subject of the present analysis. How should we interpret the above effects of leadership?

Chart 4: Group Size and Output per Scientist, given the leader's Research Experience and controlling for Group Age

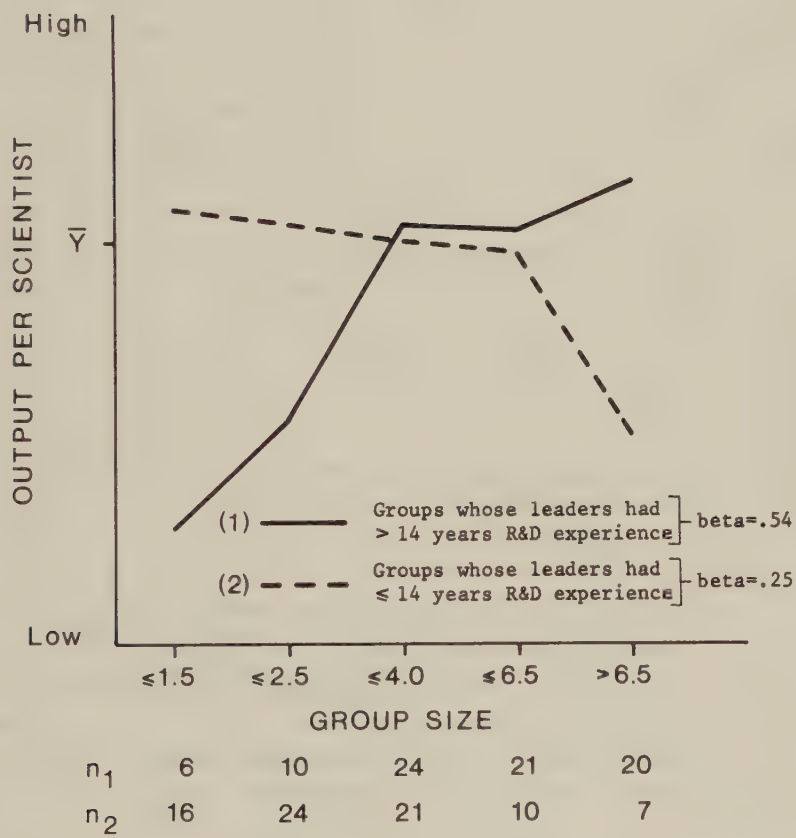
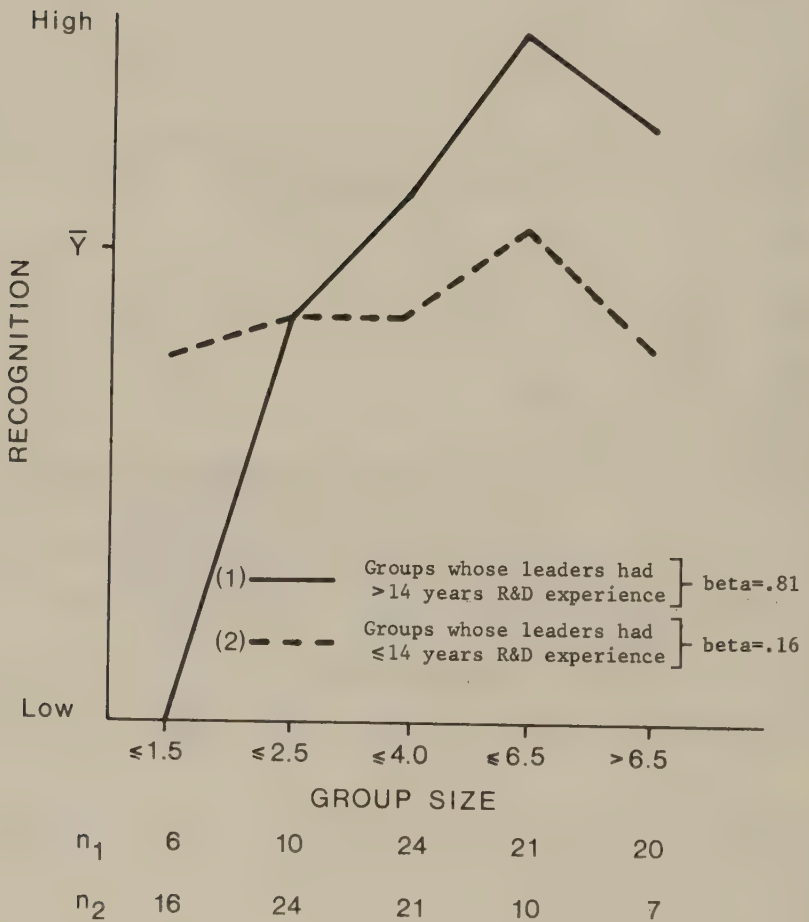


Chart 5: Group Size and Recognition, given the leader's Research Experience and controlling for Group Age



3. Leader's impacts on the performance of research groups: a typology

The difficulties of assessing the impact exercised by the leaders on the performance of their groups depend to a large extent on the complexity of the impact. Let us start therefore by defining three main ways in which an individual can influence the performance of the group to which he belongs.

i) The simplest kind of impact reflects the individual's personal performance. The output of any group is, to some extent, a sum of the individual contributions of its members. For this reason the research groups which include highly productive individuals will have higher output per person than the groups lacking such individuals. Such effect will occur independently of any group process and -- from the theoretical point of view -- may be regarded as quite trivial. But it is important methodologically. We shall refer to it as the additive effect.

ii) The second level at which an individual can make a contribution to the performance of the group is through the influence which he/she can exercise over some or all other individual group members. The presence in a group of a scientist who is a prolific "idea-man", possesses some strategic skills, or is effective in attracting material resources may have a strong reinforcing effect on the performance of other group members.

The larger the group the greater will be the number of such potential sources of reinforcement. This indeed is the very essence of the concept of group synergy. However, there is a difference between the potential and the actual relations of reinforcement. And it is against this background that the third kind of contribution of the individual to the group performance can be defined.

iii) A scientist may function as a factor lowering or heightening the level of synergy (mutual reinforcement) in the group by influencing the nature of the social, organizational, and intellectual integration in the group. We shall refer to it as the synergistic effect.

The group leaders can be expected to influence the effectiveness of their groups in each of the three ways discussed here. Chart 6 illustrates in a very schematic manner the ways in which these effects would manifest themselves statistically if they occurred one at a time.

Each of the three diagrams on the chart shows the relationship between the "per capita" performance of the groups and their size. The broken lines represent the "mean individual performance" which is defined as the hypothetical level of performance attained by the average scientist unaffected by any group factors. The diagrams assume a situation in which the leadership is the sole factor transforming an aggregate of persons into a group. This is a rather radical simplification but not entirely unreasonable, as will become clear later on.

In the diagrams, the effects of the size of a group on its "per capita" performance are measured as the deviation from the mean individual performance.

The first diagram illustrates the situation in which the group leader influences the group performance in the strictly additive sense. If his/her individual performance is significantly higher than the "mean individual performance" -- while that of the other members corresponds to the mean -- it will influence positively the per capita productivity of the group. For arithmetic reasons this influence will be the stronger the smaller the group; as a consequence we shall have a negative correlation between group size and performance. The opposite effect will result if the leader's productivity is lower than the "mean individual performance"; in that case we shall observe a reduced group performance and a positive correlation between it and the group size.

One can reasonably assume that the group leaders will tend to differ from the other members in their individual performance. They will tend to have longer research experience which should help their productivity. They will also tend to be selected on the basis of their past achievements. Other factors which are

Chart 6: Three types of impact which the leader could have on the performance of his group

Diagram I. Leader's personal performance influences the group score: "Additive effects"

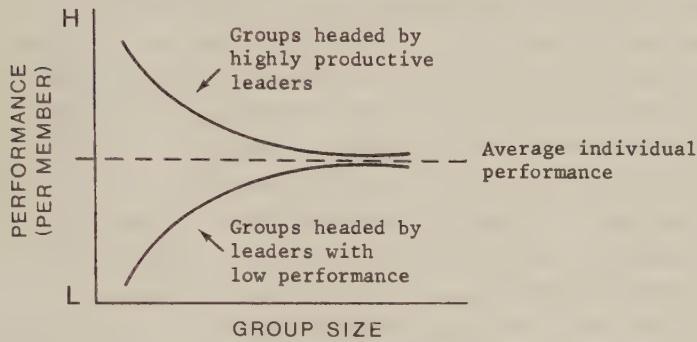


Diagram II. Leader's actions directly reinforce/suppress the performance of individual group members: "Reinforcement effects"

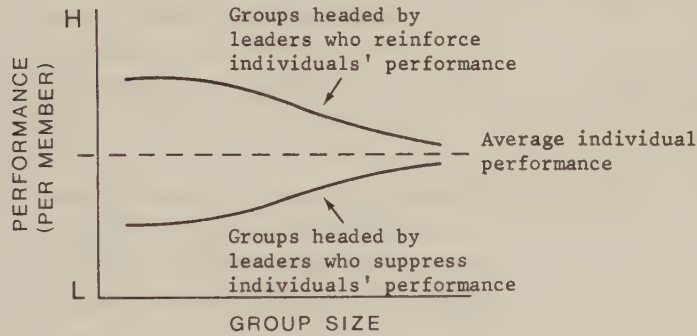
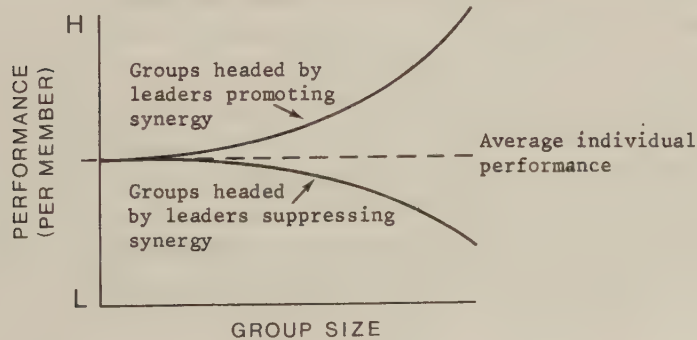


Diagram III. Leader's actions influence the level of synergy in the group: "Synergistic effects"



likely to play a role is the amount of time they can devote to research and the strength of the competitive pressures under which they work.

The second diagram depicts the situation in which the leader functions as the sole source of reinforcement for the other group members. They may benefit from the experience of the leader, his encouragement, skills, etc. On the other hand they may also be constrained by his possible mistakes and other shortcomings. The leader characteristics relevant here are: R&D experience, intellectual talents, the amount of time devoted to each group member, skill in exercising supervision, etc. In the case of positive reinforcement, the relationship between Group Size and per capita performance should yield a negative correlation since the amount of reinforcement which the leader can exercise is limited and consequently will tend to become "diluted" as the size of the group increases. As the curve on the diagram indicates, I assume that the decrease in reinforcement will initially be very mild but will accelerate with the group size. The reason for this assumption is that human relations tend to affect negatively the interactions between the leaders and non-leaders.

The two situations described above are somewhat paradoxical since, in both of them, the positive features of leadership (individual productivity and ability to help other group members) result in negative correlations between group size and performance. This is very different from what happens in the third situation. In diagram three the positive characteristics -- those which help to promote group synergy -- lead to a positive correlation between size and performance. I discussed the kinds of leader characteristics involved here in an earlier paper (Stankiewicz, 1979) arguing that the academic position of the leaders was a vital factor. The promotion of group synergy, I maintained, required a special kind of motivation on the part of the leaders. The leaders should be relatively free from institutional pressures to emphasize their own individual productivity and at the same time motivated to promote the effectiveness of the entire groups. I suggested that the

[illegible]

As far as I am concerned, I am not at all sure. It would be interesting to know. The correlation between the size and performance of the groups under the group leader may be associated with the nature of activities and reinforcement effects. The young of the group may be more likely to be active and to be reinforced than the older ones. This may be a very important factor in the group's performance. A relatively large amount of time for reinforcement, because they are still more active than the older ones, may also be a significant reinforcement effect which will be noticeable when the group is fully established. These two effects will peak when the group is just up to the point of the group is not too large. However, as the group grows larger the associative and reinforcement effects become more and more diluted; furthermore, the demands placed by the expanding group on the leader may start conflicting with his/her interests as an individual researcher and lead to a collapse of leadership of the group.

Let me now turn to the three corresponding to the groups led by the more experienced volunteers. These three I would suggest be the really mainstay of our off-line and supplemental efforts. Since the parents tend to devote relatively little time to their groups, the reinforcement efforts may be assumed to be somewhat less pronounced than for the other groups. This implies the following assumptions: the time is scarce; the work is less fun; of time has the element of corrective procedure; will need to be less productive and motivating. This will have a negative effect on the productivity of our very small group members.

for reasons stated earlier, such leaders will be motivated and able to promote group synergy, and such synergistic effects will become increasingly important as the group grows in size.

Are these assumptions and interpretations correct? In order to test them we shall have to:

- i) Consider the relevant characteristics of leaders in greater detail;
- ii) Continue our analysis of how these characteristics taken one at a time and in combinations affect the relationship between group size and performance, and
- iii) Interpret the effects thus discovered in terms of specific social-psychological processes taking place in the groups.

The remainder of this report will be devoted to these tasks.

III. THE IMPACT OF LEADERSHIP ON GROUP PERFORMANCE: FINDINGS

1. The characteristics of the leaders

There is an extensive socio-psychological literature on the leadership of small groups (for a review; see Hare, 1976). Many different aspects of leadership have been analyzed and discussed including the diversity of roles played by leaders, their power and influence, behavior consistency, etc. Many authors have emphasized the style of leadership (authorian vs. democratic; see among others Lippit & White, 1958 & 1960). Among the causal factors accounting for the variability of leader behavior, special attention has been paid to personality variables, group needs, and the culture contexts in which groups operate.

The present analysis has many points in common with the above mentioned socio-psychological approaches. We shall also focus in our analysis on the leader roles, the nature of the work process in the groups, and the importance of the institutional environment in which the groups work. However, given the fact that our main concern is with the performance of groups rather than "group climate" or "member satisfaction", the emphasis will be on the "task-management" rather than "emotional-management" aspect of leadership.^{6/} For these reasons we shall be relatively little concerned with the personality traits of the leaders or their interpersonal skills; rather we will direct our attention to the work relations in the group. This approach contrasts with that adopted by some of the other participants in the International Study (compare, Knorr, et al, 1979).^{7/}

The theoretical discussion in the preceding chapter identified a number of traits which could be expected to influence the leader's behavior and by extension his/her impact on group performance. The most important of these traits were: the leader's individual scientific performance, his/her research experience, competitive situation, the amount of time he/she can devote to work in the group, academic status, and employment.

The above variables are closely related to one another; moreover, each of them is either influenced by or constitutes an expression of the leader's position in the academic career system.

The academic career of a scientist (in Sweden as in most other countries) can be subdivided into three main stages:

i) The first stage which could be called "apprenticeship" covers roughly the first 5-6 years of a scientific career and tends to terminate with the scientist's acquisition of a PhD degree.

ii) The second stage which we might call "academic limbo" covers the next 6-10 years in which period the scientist strives to obtain his tenure.

iii) The third stage, which we shall call the "tenure", begins with the scientist's acquisition of a permanent position in the university system.

The situations of scientists finding themselves in different phases of the academic career differ strongly. The most obvious is the difference between the scientists who have reached the tenure and those who find themselves in the "limbo" stage. As noted earlier, the former are under relatively little institutional pressure to demonstrate their individual scientific competence. By contrast the people in the "limbo stage" are particularly strongly exposed to such pressures. Their "personal investment" in the academic career is much greater than that of the average scientist at the "apprentice" stage. At the same time their opportunities to continue in the system narrow down considerably, inducing an acute sense of insecurity. The scientists at the three stages of the career will also differ in their research experience, the degree to which they are "pre-selected" on the basis of past performance, and the nature of the jobs they hold at the university. With these facts in mind, let us examine the characteristics of the leaders included in our sample.

The leaders of the surveyed groups form a very heterogenous set. Tables 5 and 6 gives the distribution of leaders according to their research experience and type of employment. As can be seen, roughly 46% of the leaders (professors and lecturers) may be said to represent the "tenure" stage of the scientific career, the next 38% (docents, research fellows, some junior lecturers) could be classified as belonging to the "limbo" stage, and the remainder to the "apprentice" stage.^{8/}

Very few of the group leaders were younger than 30 years (2.6%) and almost 70% were in the age range between 30 and 47 years. Most of the leaders held "old style" doctoral degrees (66.5%), an additional 12.3% held "new" doctoral degrees, and 12.4% licenciature degrees. Less than 10% held only basic degrees.^{9/} As could be expected the research experience, age, academic degree and type of employment were rather closely related to each other.

Table 5 Leaders' academic position/employment

	<u>N</u>	<u>%</u>
Professors	60	34.5
Lecturers	20	11.6
Docents	29	16.9
Research fellows (forskarass.)	20	11.6
Junior Lecturers	16	9.3
Other (junior)	<u>27</u>	<u>15.8</u>
	n=172	100.0

Table 6 Leaders' research experience

<u>Years R&D</u>	<u>%</u>
- 5	10.5
5 - 10	25.5
10 - 15	21.6
15 - 20	23.8
20 -	<u>18.6</u>
	100.0

Table 7 gives the time budget of an average leader. It can be seen that the average leader devotes about 43% of his time to research work. Of this time, roughly 75% is concentrated to the group. There exist, however, strong differences in the time budget depending on the leader's employment (see Table 8).

Table 7 Average time budget of a group leader

<u>Function</u>	<u>% time</u>	<u>s.d.</u>
R&D in the group	31.5	21.9
R&D outside the group	11.3	13.9
Administration	17.8	13.9
Teaching	25.4	14.0

Table 8 Leaders' time for research in and outside the group
by type of employment

<u>Employment</u>	<u>% time in the group</u>	<u>% time outside the group</u>
Professor	22	13
Lecturer	21	5
Docent	41	14
Research ass.	40	10
Other	43	11

Let us now pull these individual bits of information together by arranging them into three profiles corresponding to the stages of the leaders' research career. These profiles are given in Table 9.

Table 9 Leader profiles according to the stage of academic career

Leader properties	The stage of leader's career		
	"Apprenticeship"	"Limbo"	"Senior"
R&D experience (median years)	6	12	24
Typical employment	Stipend holder, Junior assist.	Docent, Re-search fellow (forskarass)	Professor, Lecturer
Status differential (in relation to other group members)	Low	High	Very high
% of time for research	55	55	30
Institutionally induced competitiveness	Moderate	Strong	Weak

It was suggested in the preceding chapter that the behavior of leaders in the groups was a function of their location in the academic system. This hypothesis was based on the fact that the relationship between Group Size and Performance varied, depending on the research experience of the leaders. We shall now proceed to test the hypothesis by increasing the specificity of analysis. Instead of looking only at the pairwise interactions between Group Size, on the one hand, and leader's R&D Experience or his Time in Group on the other, we shall consider jointed interaction effects of these three variables. Furthermore we shall examine directly the interactions between Group Size and the type of Leader's Employment. The latter variable is, after all, the best direct indicator of the scientists lo-

cation in the academic system. Before going into these matters, however, let us examine a few simple relationships between the leaders' characteristics and their own productivity and group performance.

2. The leaders' characteristics, their individual productivity and group performance

It was hypothesized earlier that the individual productivity of group leaders would vary with the stage of academic career at which they find themselves, and that this would affect the group performance. The plausibility of this hypothesis is confirmed by the fact that there is a significant correlation ($r=.55$) between the groups' total output and the number of papers published by the leaders.

A further examination of the data disclosed that the number of papers authored by the leader was indeed related to his research experience, the time he devoted to work in the group, and his academic status. Charts 7-9 illustrate these relationships, none of which appears to be particularly strong but which, nevertheless, go in the predicted direction. In particular it should be noted that the effects of the pressure to publish, which we said would depend on the location of the scientists in the career system, are quite noticeable. The leaders who find themselves in the middle phase ("limbo") of the career (docents and research fellows) were clearly more productive than the scientists in the "apprentice" or "tenure" stage of the career (note that these differences emerge after the effects of the "time in the group" and "research experience" have been controlled for).

The above effects, however, must be treated with caution since the relationship between the performance of a group and that of its leader is two-sided. Indeed the leader's personal productivity is related to the number of collaborators he has in the group ($r=.38$). Moreover, as already noted, the group productivity -- which obviously affects the productivity of the

Chart 7: Leader's Time in the Group and his Individual Productivity, controlling for Research Experience and Employment

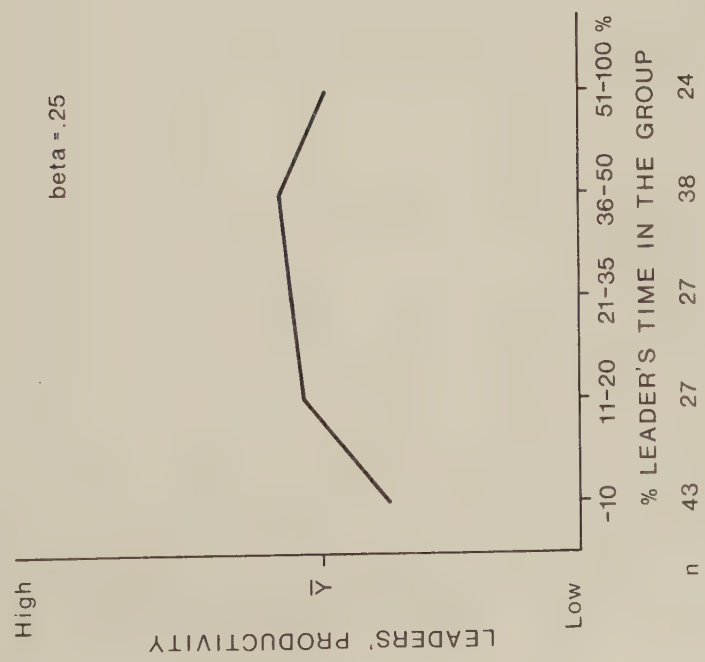


Chart 8: Leader's Research Experience and his Individual Productivity, controlling for Time in the Group and Employment

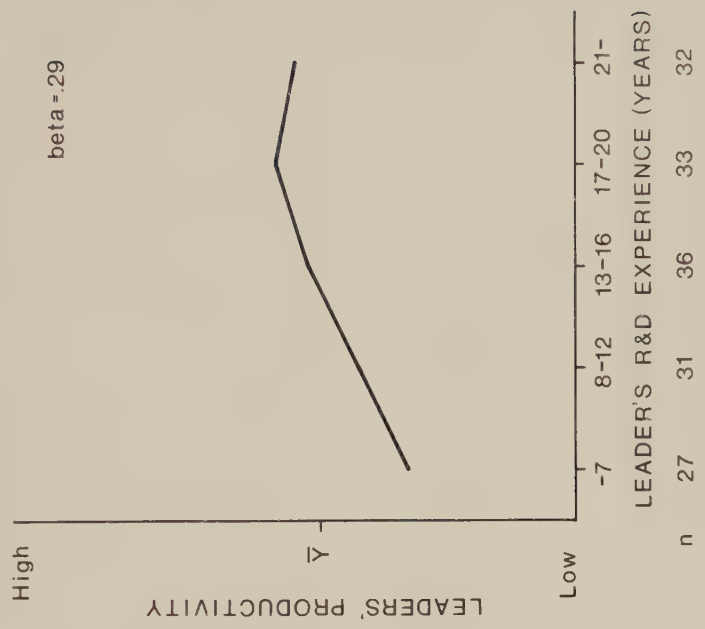


Chart 9: Leader's Employment and his Individual Productivity, controlling for Time in the Group and Research Experience

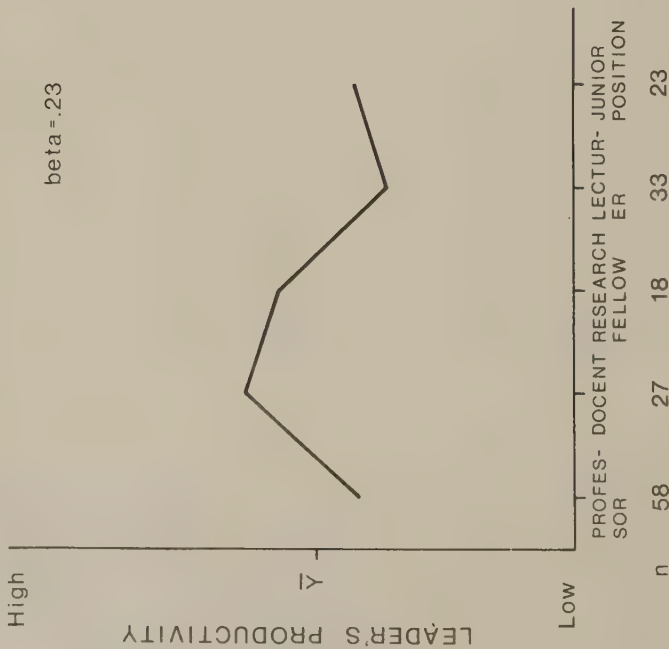
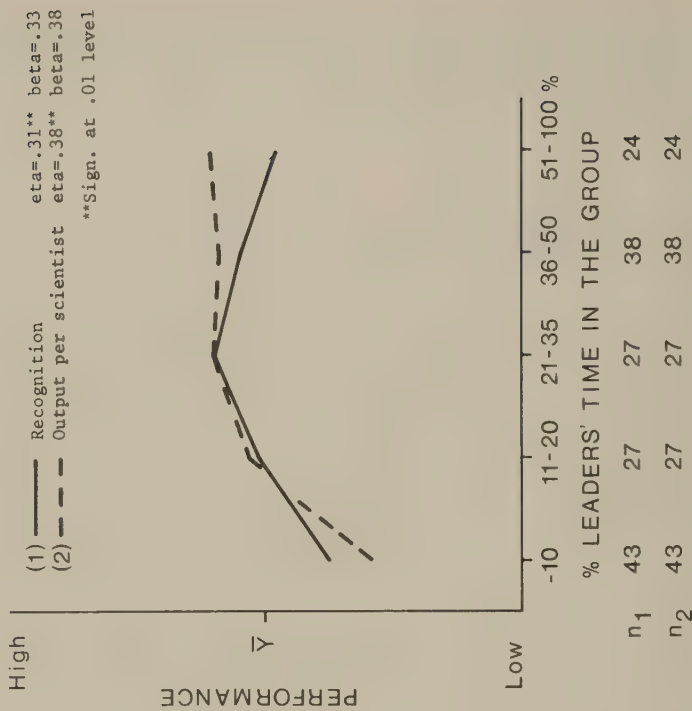


Chart 10: Leader's Time in the Group and Group Performance, controlling for Research Experience and Employment



leader -- is itself strongly influenced by the interactions between group size and the research experience of the leaders. Hence a more complex analysis is required if we are to test our hypothesis.

What of the direct effects of leader characteristics on the group performance? Charts 10-12 describe the impact of the leaders' Time in the Group, R&D Experience, and Employment on the index of Recognition and group's Productivity (Output per Scientists). The tentative conclusions which emerge are as follows:

- The amount of time which the leader spends with the group is related to performance in a curvilinear manner; performance improves as the % of time increases up to 35 after which it stabilizes or even decreases. This result, like the others involving the time factor, is somewhat counterintuitive.
- The amount of leader's R&D experience bears a fairly strong, largely linear relationship, to the index of Recognition but seems unrelated to the groups' quantitative performance. This suggests that the index of Recognition might be partly a result of a halo effect: the leader's own scientific reputation which increases with time may be transferred to the group as a whole. However, it is not possible to say how important this effect actually is.
- The academic position appears to have no statistically significant effect on the performance of groups. If any tendency can be discerned in the curves on chart 12, it is that, other things being equal, scientific status is inversely proportional to Recognition. If true, that would be a surprising result. Indeed, it would contradict our main hypothesis.

However, just as in the case of the factors influencing the leader's personal productivity the above mentioned relationships should not be accepted at their face value. I present them here merely to put them on the record. The analysis summarized in the preceding chapter have shown clearly that such leader

Chart 11: Leader's Research Experience and Group Performance, controlling for Time in the Group and Employment

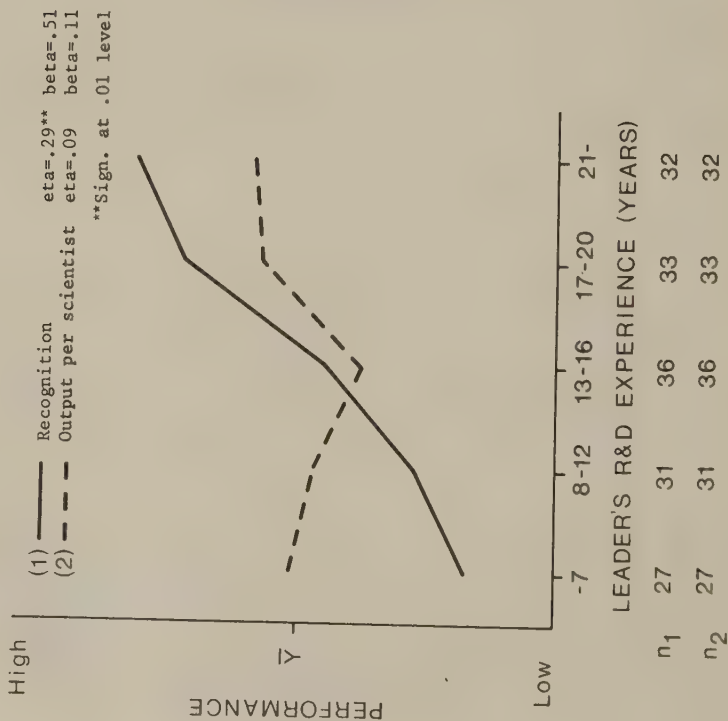
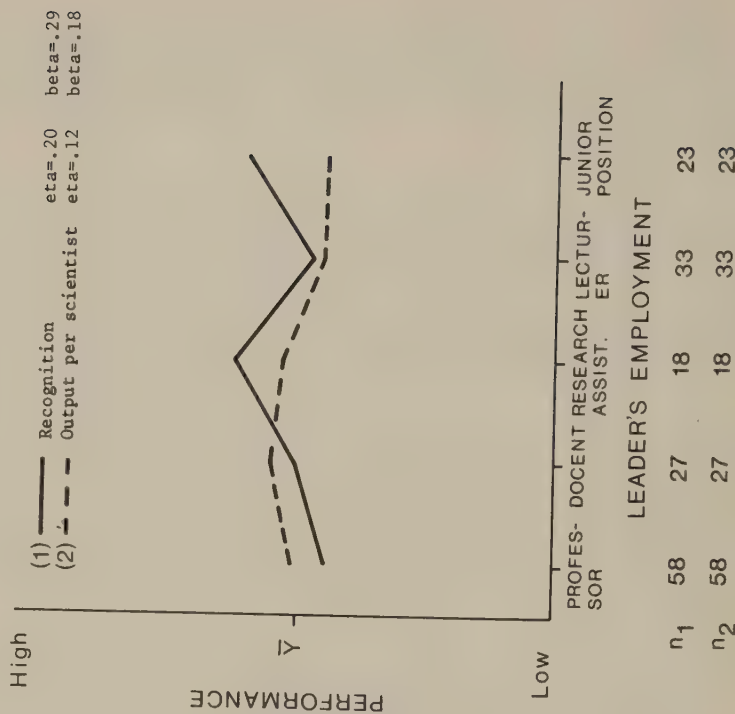


Chart 12: Leader's Employment and Group Performance, controlling for Time in the Group and Research Experience



characteristics as R&D Experience or Time with the Group cannot meaningfully be related to group performance without taking into account their interactions with the group size. In other words we must return to the interaction models used in the earlier parts of this paper.

3. The joint effects of the leader's Research Experience and his Time in the Group on the relationship between Group Size and Performance

The leader's Research Experience and his Time with the Group are both related to his location in the career system. We have noted earlier that each of these variables interacted with group size when used to predict performance. While the interactions involving the leader's Research Experience seemed to be easy to interpret, those involving Time in the Group were a bit odd. Given the fact that the correlation between Research Experience and Time in the Group is by no means perfect, one may speculate as to whether the true effects of these factors are not obscured by some higher order interactions between them. One would like therefore to ask: is the pattern of interaction between Time in the Group and Group Size independent of the leader's R&D Experience? Or, even more importantly, is the pattern of interaction between Experience and Group Size the same no matter what proportion of his time the leader spends with his group? Let us therefore examine what happens to the relationship between Groups Size and Performance when the two leader characteristics are controlled simultaneously.

In order to do that I subdivided the sample into four subsamples according to the scheme given below:

Subsample 1: Group headed by leaders who had 15 or more years of R&D experience and who devoted at least one third of their time to work in the group.

Subsample 2: Groups headed by leaders who had 15 or more years of R&D experience and devoted less than one third of their time to work in the group.

Subsample 3: Groups headed by leaders with less than 15 years of R&D experience who devoted at least one third of their time to work in the group.

Subsample 4: Groups headed by leaders with less than 15 years of R&D experience who devoted less than one third of their time to work in the groups.

Since the size of the resulting subsamples was quite limited, I could not continue using the Multiple Classification Analysis. In what follows I adopt instead the Multiple Regression approach. Just as in the earlier analysis, all the results presented here have been obtained while controlling for the effects of Group Age.

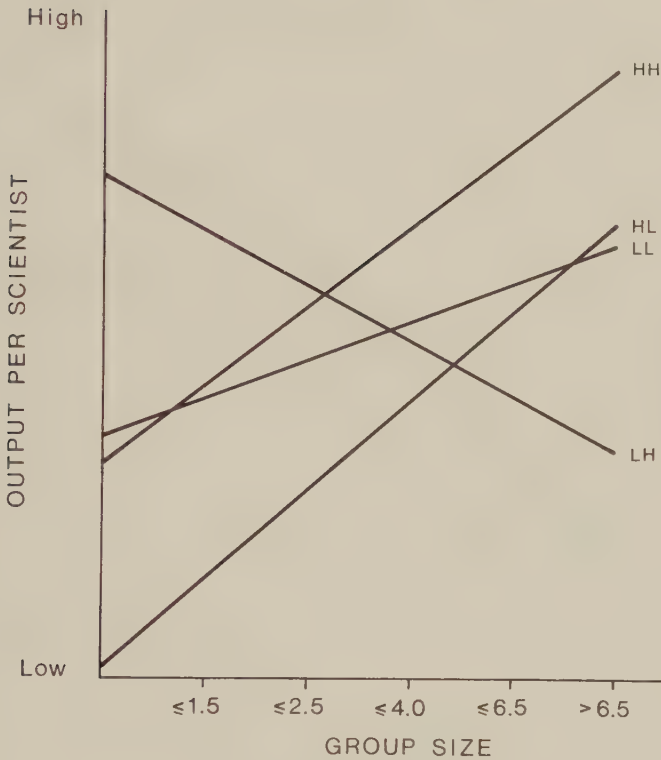
The results shown on Charts 13-14 do seem to go a long way towards explaining the somewhat confusing trends emerging from the earlier analysis.

Let us first consider the relationship between Group Size and Output per Scientist.

Chart 13 suggests the existence of a strong direct influence of the leader's personal productivity on group performance. The leader's productivity, roughly indicated by the point of origin of the regression slope,^{10/} appears to depend both on the amount of time which he/she devotes to work in the group and his/her research experience. Thus, the younger leaders who devote much time to work in the group appear to be most productive, while the least productive are the more experienced leaders who spend little time with their groups. The fact that the less experienced leaders are the most productive is consistent with the hypothesis that such leaders are under especially strong pressure to demonstrate their individual productivity.

Furthermore, the diagram suggests that it is the leader's Research Experience, rather than his Time in the Group, which accounts for the synergistic effects. This can be deduced from the fact that the regression slopes for the groups headed by

Chart 13: Group Size and Output per Scientist, given the leader's Research Experience and Time in the Group and controlling for Group Age (Regression slopes)

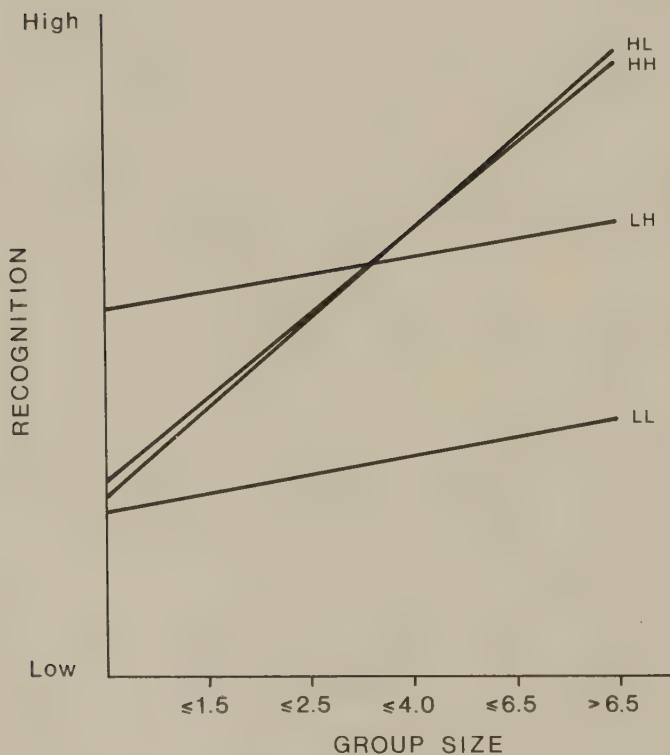


	beta	n
(1) HH = HIGH R&D EXPERIENCE + HIGH INVOLVMENT	.31*	35
(2) HL = HIGH R&D EXPERIENCE + LOW INVOLVMENT	.43**	45
(3) LH = LOW R&D EXPERIENCE + HIGH INVOLVMENT	-.22	45
(4) LL = LOW R&D EXPERIENCE + LOW INVOLVMENT	.16	38

**Sign. at .01 level

* Sign. at .05 level

Chart 14: Group Size and Recognition, given the leader's
Research Experience and Time in the Group
and controlling for Group Age
(Regression slopes)



	beta	n
(1) HH = HIGH R&D EXPERIENCE + HIGH INVOLVMENT	.53**	35
(2) HL = HIGH R&D EXPERIENCE + LOW INVOLVMENT	.50**	45
(3) LH = LOW R&D EXPERIENCE + HIGH INVOLVMENT	.17	45
(4) LL = LOW R&D EXPERIENCE + LOW INVOLVMENT	.10	38

**Sign. at .01 level

senior leaders are positive irrespective of the amount of time they spend in the groups. Thus the hypothesis that group synergy depends on the leaders' involvement (in terms of time) receives no support from our data. Note, however, that the amount of time which the seniors spend in the groups does affect the level of the regression lines. This seems to imply that the leaders' involvement affects the amount of reinforcement which they give other individual group members. However, given the fact that we cannot study the possible curvilinearities behind our regression lines, the above interpretation must be treated with caution.

The remaining two slopes on Chart 13, LH and LL, are more difficult to interpret since they are statistically less reliable. It seems rather clear that the performance of the groups headed by junior leaders who spend much time with the group is very much a function of the leaders' individual productivity (slope LH). It is plausible to assume that such leaders should also exercise some reinforcing impact on the individual group members; however, it is rather difficult to attribute to them any synergistic effects. The overall result is a negative slope.

The LL slope is very weak ($\beta = .16$) and positive. This slope may be the result of the low individual productivity of the leaders combined with the absence of any significant synergistic effects. However, given the weakness of relationship and its statistical unreliability we can only guess.

Chart 14, which interrelates Group Size and the index of Recognition, generally confirms the results of the preceding analysis. (Note that the index of Recognition is not a per capita measure and that the only thing we can go by here are the differences between the slopes and levels of the regression lines). Thus we note that only in the case of the groups headed by senior scientists is there a statistically significant correlation between Group Size and the index of Recognition. The weak relationship between Size and Recognition in the case of LH and LL lines is wholly due to the cumulative increase in the total output of the groups.^{11/} In the case of HH and HL

lines, on the other hand, the effects of size are greater than what could be accounted for in terms of the effects of cumulative output.

The results summarized in charts 13 and 14 confirm our earlier analysis and help to clarify some of the uncertain points, especially those concerning the effects of leaders' Time in the Group on group performance. The shape of the curves in chart 2 can now be accounted for in terms of a) the relationship between leaders' Time in the Group and their individual productivity, b) the correlation between leaders' Time in the Group and their Research Experience, and c) the possible reinforcing effects associated with leaders' involvement in the groups. Still more importantly, the above analysis shows that the originally identified interactions between leaders' Research Experience and Group Size manifest themselves even when the effects of Time in the Group are controlled for. This constitutes a further indirect confirmation of the hypothesis that the leaders' ability to promote group synergy is related to their institutional status. However, it by no means eliminates all ambiguities associated with the hypothesis. After all, it could be argued that the interactions between Research Experience and Group Size are not at all due to the underlying differences in the institutional situations of the leaders but, rather, to the fact that senior leaders possess greater managerial experience and are preselected on the basis of their managerial skills. To tackle this problem we must introduce into our analysis a more detailed measure of the leaders' position in the academic system. The leaders' employment constitutes such a measure.

4. The effects of the leader's academic position on the relationship between the size of the groups and their performance

Since there is a close correlation between the academic employment of scientists and their research experience, the separation of the effects which each of these variables has on group performance is very difficult indeed. Our sample is too small to produce subsamples in which both these variables could be

satisfactorily controlled. However, there exists an indirect approach to the problem.

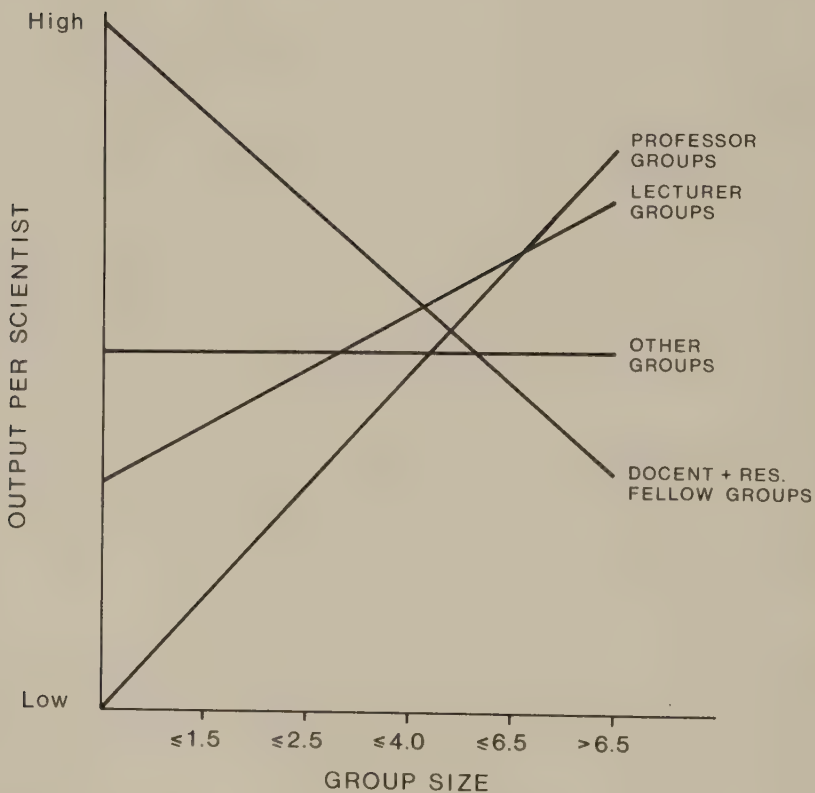
Even if there is a rather close correlation between the academic employment of the leaders, their R&D experience, and Time for research, we can still ask which of these variables or their combinations constitutes the most powerful control factor in the sense of producing strongest, "cleanest", and thus most interpretable, results. Specifically: will the pattern of relations that emerge between Group Size and Performance, when we control for the leaders' academic employment, be as clearcut and significant as the one which emerged when the leaders' R&D Experience and Time in the Group were controlled simultaneously?

In order to answer this question our sample was split into four subsamples according to the academic position of the leaders. This operation was not very easy since it was necessary to avoid subsamples that were too small. After considering various alternatives we decided to use the following four sets of groups:

- i) Professor groups,
- ii) groups headed by Docents and Research Fellows (forskarass.),
- iii) groups led by Lecturers (incl. Junior Lecturers), and
- iv) groups led by Junior Scientists occupying lower academic positions.

This split is fully acceptable as far as the subsamples i), ii) and iv) are concerned. They clearly correspond to the "tenure", "limbo", and "apprenticeship" stage of the leader's career. Sub-sample iii), however, is heterogeneous since it consists of a majority of groups led by full Lecturers (who represent the tenured stage of scientific career) and a minority of groups headed by Junior Lecturers (some of whom are quite similar to Docents and Research fellows while others reassemble most closely the Senior Lecturers). In order to be able to consider the lecturers as a category in our analysis it was necessary to keep both types together. This must be remembered while interpreting the results, which are summarized in Charts 15 & 16.

Chart 15: Group Size and Output per Scientist, given
the leader's Employment and controlling for
Group Age
(Regression slopes)

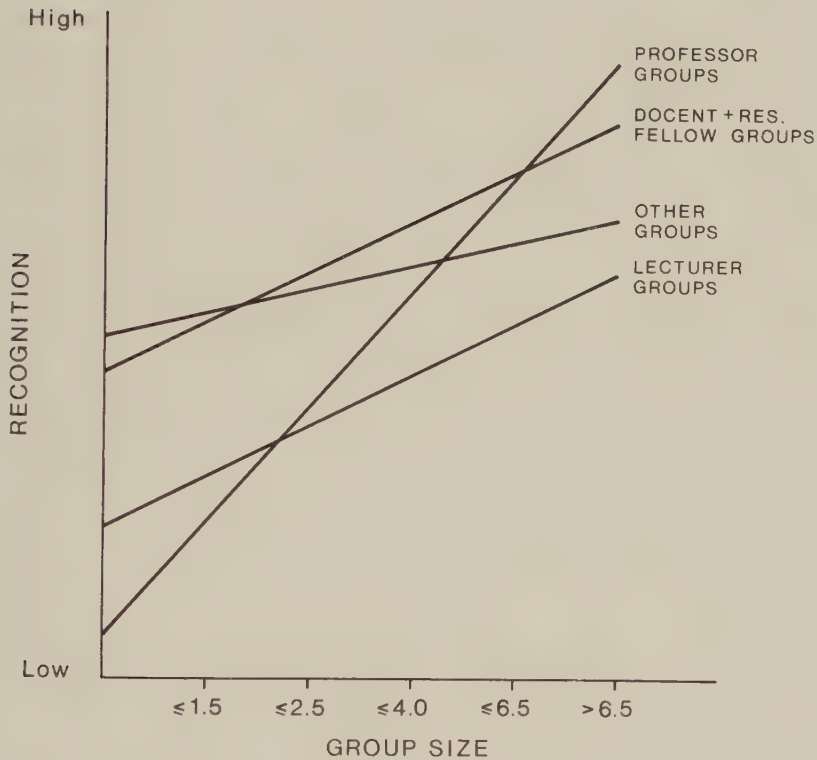


	beta	n
(1) PROFESSOR GROUPS	.52**	59
(2) LECTURER GROUPS	.22	33
(3) DOCENT + RES. FELLOW GROUPS	-.35*	47
(4) OTHER GROUPS	.00	20

**Sign. at .01 level

* Sign. at .05 level

Chart 16: Group Size and Recognition, given the leader's
Employment and controlling for Group Age
(Regression slopes)



	beta	n
(1) PROFESSOR GROUPS	.60**	59
(2) LECTURER GROUPS	.26	33
(3) DOCENT + RES. FELLOW GROUPS	.28	47
(4) OTHER GROUPS	.12	20

**Sign. at .01 level

The trends depicted in charts 15 & 16 are both stronger (compare the betas) and more distinct than those emerging from charts 13 & 14. Looking at chart 15, which describes the impact of Group Size on Output per Scientist, we can clearly distinguish between three types of relationships. In the case of research groups led by scientists who find themselves in the "apprentice" phase of their career, we find virtually no relationship between Group Size and Productivity. In the case of scientists belonging to the intermediate group (docents/research fellows) there is a marked negative relationship between Size and Productivity. In the case of groups led by scientists in the tenured phase of career, the relationship is clearly positive. This constitutes a rather striking confirmation of the hypothesis concerning the impact of the leader's academic position on the relationship between the size of research groups and their performance. Furthermore the slopes of the regression lines in chart 15 indicate that it is indeed the position of the leader and not only his/her research experience per se that influences group synergy. For, if the opposite were true, we would expect very weak - or no - synergistic effects in the groups headed by junior scientists, some synergistic effects in the groups headed by docents and research fellows, and strong synergistic effects in the groups headed by seniors. After all managerial experience should grow continuously with the scientists' research experience; the selection mechanisms should also operate with some continuity (in the sense that the scientists at the intermediate stage of their careers should be more preselected than those at the apprenticeship stage but less so than those at the tenure stage). But, clearly, there is no such continuity when we look at the corresponding changes in the relationship between Group Size and Performance (as we move from the groups headed by junior scientists, through those led by researchers at the intermediate stage of their career to those headed by the seniors). There simply is no sign of synergy in the groups led by docents and research fellows; indeed, if anything, such groups seem to exhibit a sort of anti-synergy.

The trends exhibited in Chart 16 confirm the above general conclusions. The Professor groups have the steepest slope, while

the groups headed by the junior scientists the flattest. Only in the case of the former is there a significant relationship between the group size and Recognition after the effects of total output were controlled for.

Reassuring as they are, the above results must be treated with caution. Not only do they require further resting on new data sets but also a more detailed elaboration in terms of the present data. Up to now we were concerned with the effects of leadership on group performance without considering directly the specific socio-psychological processes through which these effects are brought about. In the theoretical discussion in Chapter II I merely indicated the general nature of such processes. The group synergy - I said - depended on the pattern of social and intellectual integration in the groups. If so, we should expect that the properties which determine the leaders' impact on group synergy should also influence significant aspects of group integration. This should be particularly true about the leaders' academic position. In the next chapter we shall try to establish whether or not this is the case.

IV. LEADERSHIP AND GROUP STRUCTURE

1. Introduction

The present analysis focuses on three dimensions of group integration:

- i) the pattern and intensity of communication and collaboration in the groups;^{12/}
- ii) the degree to which the groups are perceived as cohesive by their members, and
- iii) the pattern of "division of labor" or, better, "technical role differentiation" in the groups.

The above aspects of integration, which taken together give a fairly detailed picture of the structure of the groups, will be systematically related to those characteristics of leaders which were found to influence group performance.

2. Supervision, communication and collaboration: a sociometric analysis of the groups

There are several ways to measure the level of interaction among the members of a research group. We may inquire about the frequency with which they communicate with one another, who collaborates with whom, or who works under whose supervision, and so on. Interpreting this sort of data we must answer questions concerning the over-all magnitude of the interactions, the way the group is structured, the content of interactions and the effects they have on the individual group members. Here we will attempt to answer the first two of these questions by subjecting the groups in our sample to a quasi-sociometric analysis. The analysis is quasi-sociometric, because a proper sociometric analysis would require complete knowledge of all pairwise relationships under investigation (who in the group supervises whom, who collaborates, or communicates, with whom etc.). In our survey we could not obtain such detailed information. However, we do know for each individual group member how many collaborators

he/she had in the group and how many other members he/she considered particularly important from the point of view of communication. This data is sufficient to give us an approximate picture of the sociometric structure of the studied groups. Let us consider this structure relationship by relationship.

2.1 Supervision

The relationship of formal supervision is very important in academic groups. Supervision means the review of work done by group members by one or more senior scientists. We have inquired about the number of group members whom the leaders supervised directly. Despite the fact that in some groups -- especially the large ones -- there was more than one supervisor, the correlation between group size and the number of scientists supervised by the leader was very high ($r=.80$). This confirms the fact that the leaders occupy the central position of scientific authority in their groups. This position (as measured by the number of supervised scientists) is not affected by the leader's status, research experience, or time devoted to the group.

Supervision is a very broad and somewhat formal concept. What sort of group structure emerges if we instead look at the pattern of communication among group members?

2.2 Communication

Since the groups surveyed tended to be relatively small it was to be expected that encounters between group members would be very frequent. For this reason we decided to inquire about the instances of communication which the group members regarded as particularly important in their research work. More specifically we asked our respondents (including leaders) to indicate the number of other scientists in the group whom they considered as especially important sources for useful technical ideas or important technical information.^{13/} Charts 17 & 18, in which the numbers of important communicators reported by the leaders

Chart 17: The number of persons giving the leaders/non-leaders important technical information by Group Size

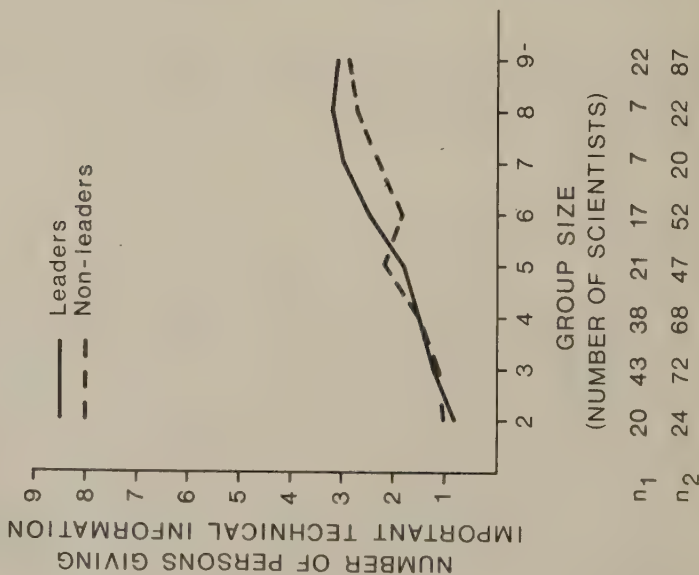
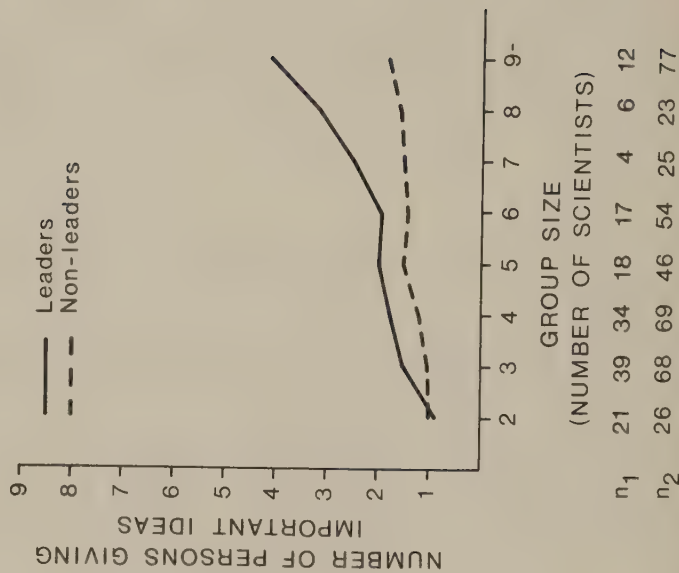


Chart 18: The number of persons supplying the leaders/non-leaders with important technical ideas by Group Size



and non-leaders are plotted against group size, summarize the results obtained.

When we consider the number of persons supplying "important technical information" we note that the differences between the leaders and the non-leaders are very small indeed. On the whole, it appears that scientists regarded every second or third group member as a particularly significant source of technical information. Although there are some variations in these numbers: these variations were found to be unrelated to the characteristics of the leaders.

Turning now to the graph showing the numbers of persons supplying "important technical ideas" we observe a somewhat different situation. First of all, we note that the group members tend to report relatively few sources of important ideas. The number of such sources increases very slowly with group size. This suggests that the intellectual cross-fertilization which is often regarded as an important source of group synergy might, in reality, be a minor factor. Such a conclusion, however, would be premature of this point.

The same chart shows that, as opposed to other members, the group leaders reported relatively numerous sources of important ideas - the ratio being roughly one source per 2-3 scientists. Thus the leaders looked as if they were collectors of ideas generated by the group members. This fact does suggest that the leaders are reinforced by the rest of the group but does not imply any synergistic effects. However, we have also some data which shows that the leaders function not only as the collectors of ideas generated in the group but also as their disseminators.

In addition to asking the group members to indicate the number of sources of ideas and information, we asked them which category of personnel was the most important. Table 10 summarizes the responses of the scientists (non-leaders).

Table 10 The non-leaders' most important sources of technical informations and ideas

Type of source	% scientists indicating the source	
	technical inform.	technical ideas
Group leader	36	53
Other scientists in the group	38	32
Technical personnel	15	3
Missing data	<u>11</u>	<u>12</u>
	100	100

The table shows that the leaders are disproportionately often cited as the most important source of "technical information". However, it is in the case of "technical ideas" that their dominance is greatest. In fact more than half of the group members regarded the leader as the most important source of such ideas. (Note also that technical personnel play a significant role as a source of information, but a very limited one as a source of ideas).

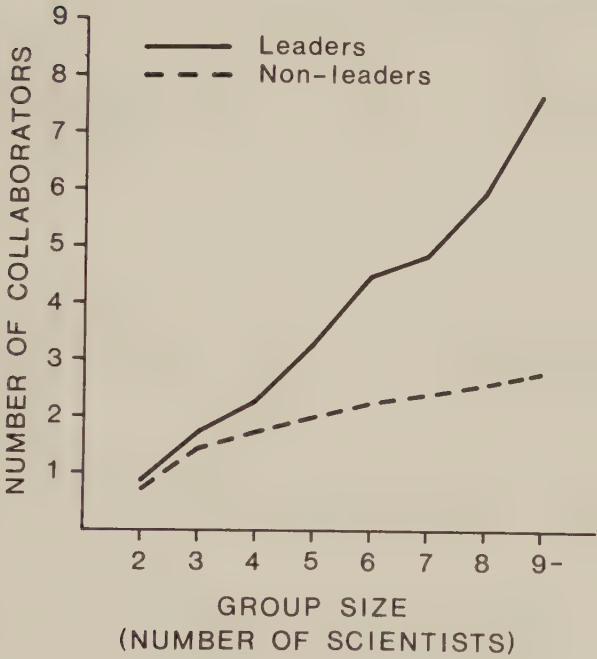
The above results suggest that group leaders function as "brokers of ideas" in their groups. For this reason they could be expected to influence the process (creating) synergy in the groups. It was therefore disappointing to see that the above described patterns of communication did not seem to vary depending on the leaders academic status.

Let us now consider the pattern of collaboration in the groups.

2.3 Collaboration

Collaboration is a somewhat diffuse term which in research can mean anything from intimate cooperation over long periods of time to very marginal exchanges of services. In order to give

Chart 19: The number of collaborators reported by the group leaders/non-leaders in relation to Group Size



n_1	20	40	31	17	15	6	6	19
n_2	24	70	80	50	51	30	26	83

the term a well defined meaning we decided to limit its application to those cases in which cooperation between scientists resulted, or was expected to result, in a joint publication/report.

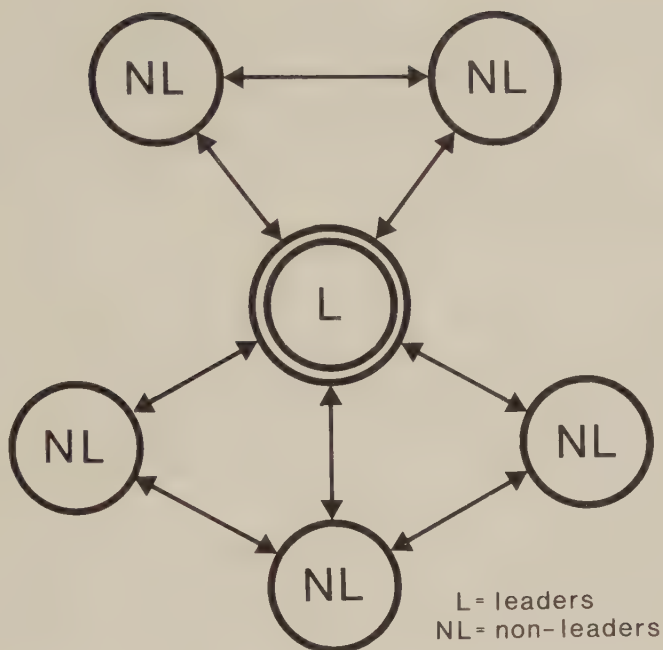
Chart 19 plots the number of collaborators reported by the leaders and non-leaders, respectively, against group size. Once again we can observe a strong difference between leaders and non-leaders. The former report close collaborations with most of the group members. This is a very significant finding since it indicates the nature of the bond which holds the groups together. The number of collaborators reported by the non-leaders was low - the average being slightly over two. Again, these patterns seem to be unrelated to the academic position of the leaders.

2.4 Discussion

How shall we interpret the above findings? Clearly our hypothesis stating that the interactions in groups are affected by the institutional characteristics of the leaders is not confirmed by the data. At the same time the results described so far seem to give certain hints concerning the group structure - hints which call for a redefinition of our concept of integration in the groups. Let us follow up these hints.

It seems now established beyond any doubt that the leaders occupy central positions in their groups. Indeed it is justifiable to say that the groups grow around their leaders. This becomes especially apparent if we reconstruct, on the basis of the data reported above, what may be a typical sociometric structure of a research group.

Let us consider a group consisting of 6 scientists. In such a group the leader would collaborate, on average, with 4-5 group members while the non-leaders would collaborate with 2-3 members each. This would be compatible with the following structure.



Information and ideas are likely to flow roughly along the same lines.

The graph must be treated cautiously since it represents a hypothetical situation based on averages. However, the structure it outlines is rather plausible.

According to the graph the typical group has neither the "wheel" structure, whereby all the links in the group would be maintained through the leader, nor does it represent a fully interconnected network. What we get is rather a set of subclusters each involving 2-3 scientists and linked together by the leader.

Our data indicates clearly that non-leaders do not tend to engage in extensive collaboration among themselves. The average number of collaborators reported by scientists in the groups consisting of 9 or more members was between 2-3, roughly the same as for 6-person groups. This tendency to form small cliques or subgroups would strongly limit the intensity of inter-

action in the groups and, by extension, their synergy were it not for the presence of the leaders who, linked to almost all group members, can function as the "spindles" weaving together the ideas and results produced by the individual group members and their subgroups. Thus it seems that a typical leader does not merely influence the organization of the group; rather he/she embodies that organization.

This calls for a modification of certain concepts introduced in the theoretical part of the paper. It was implied there that group synergy would depend on the amount of interactions in the groups as measured by person-to-person links/encounters. The analysis presented above suggests that this may be too simple a view. Clearly, a central person who mediates the contacts between individuals may become a functional equivalent of person-to-person interactions in the group. The leaders act as such central persons. So perhaps it is not the relative frequency of direct interactions among the individual group members that is crucial for our analysis but the quality of relations (social and intellectual) between the leaders and the group members. Let us therefore turn to such more qualitative aspects of group integration starting with the perceptions that other group members have of the leaders.

3. The attitudes of the group members to the leaders

In our questionnaires we included a series of items concerning the group members' perception of the leaders' characteristics and influence on the members. The most important of these were:

- 1) The perceived frequency of contact between the leaders and the non-leaders
- 2) The effects attributed to these contacts by the non-leaders
- 3) The perceived degree of support given the non-leader by the leaders
- 4) Their perceived leadership qualities
- 5) The perceived professional qualifications of the leaders

- 6) Their personalities and character
- 7) The perceived importance of the leader's support in the choice of research problems for the non-leaders
- 8) The perceived degree of control exercised by the leaders over the non-leader's direction of work.

All the above attitudes were measured on ordinal five point scales.

There was a strong tendency on the part of the group members to evaluate the leaders positively. The high skew of the variables and their low variances suggest that we should be cautious in interpreting them.

The correlations among the variables are given in Table 11. It can be seen that all the variables, with the exception of item 7, are strongly intercorrelated.^{14/}

Table 11 Correlations among the variables describing the groupmembers perception of the leader

		1	2	3	4	5	6	7
Contact with the leader	1							
Effects of contacts with the leader	2	.71						
Leader's support of the scientist's work	3	.70	.71					
Leadership qualities	4	.54	.60	.62				
Professional ability	5	.55	.67	.67	.69			
Character	6	.54	.59	.62	.66	.75		
Influence on the scientist's prob. choice: decision	7	.10	.17	.09	.10	.13	.09	
Influence on the scientist's prob. choice: leader's support	8	.39	.44	.37	.33	.31	.30	.52

How are these perceptions and evaluations related to the three characteristics of the leaders (R&D Experience, Time in Group, and Employment) on which our analysis focuses?

It appears that the correlations are very weak indeed. Only two items are significantly related to the amount of time the leader devotes to the work in the group: "Frequency of contacts" and "Effects of contacts". (After controlling for the effects of the other two leader characteristics, the correlations are approximately linear; MCA betas equal .31 resp .29).

The time factor plays virtually no role in relation to the remaining variables measuring the members' participation of the leader.

The research experience of the leader appears to have slight curvilinear effect on practically all perceptions of the leaders. These perceptions tend to become more positive with the increase of the leader's R&D experience during the first 20 years after which there is some decline. However, none of these tendencies is statistically significant. The leader's research experience seems to have the strongest effect on the group members' evaluation of the effects of contacts with the leaders (MCA beta = .25).

The effects of the leader's employment also tend to be very limited and, in addition, not very consistent across all the dependent variables. They are relatively strongest in the case of the perceived frequency of contacts (beta=.25). The ranking of the leaders in terms of this variable (from most contacts to least contacts) was: 1. Lecturers, 2. Junior scientists, 3. Research Fellows, 4. Professors, and 5. Docents. (Note that this ranking was made after the effects of the leader's time in the group and research experience were taken into account).

No matter how we interpret the above findings, the results cannot be said to contribute much to the explanation of the relationship between type of leadership and group performance. On the whole there seems to be very little connection between the

leader's location in the academic system and the way he/she is perceived by the group.

4. The perceived group integration and the characteristics of the leaders

The results of the sociometric analysis presented at the beginning of this chapter raise the question as to whether the overall frequency of person-to-person contacts was necessarily the best measure of group integration. In our study, group integration was also measured by asking the group members to evaluate various aspects of it subjectively. Let us therefore consider the relationship between these perceptual measures and the characteristics of the leaders.

Five measures of perceived integration of the groups were used.^{15/}

- a. The degree of coherence of the groups research program
- b. The degree of participation of the group members in the planning of research in the group
- c. The degree of cooperation among the group members
- d. The sense of belonging to the group, as experienced, by individual members
- e. The members' feeling of receiving psychological support.

The above five items seem to cover all the main aspects of group integration from intellectual coherence, through organizational integration to psychological cohesiveness. Table 12 gives the correlations among the items, which appear to form a relatively well interconnected cluster.

Table 12 Correlations between the measures of group integration

		(1)	(2)	(3)	(4)
Coherence of res.progr.	(1)				
Participation in planning	(2)	.44			
Cooperation	(3)	.50	.42		
Feeling of be- longing	(4)	.47	.36	.65	
Psychological support	(5)	.21	.19	.52	.44

The five measures of group integration were related to three predictors: the leader's research experience, his time with the group, and academic employment. As in the preceding analysis, the predictors were introduced simultaneously.

The general expectation was that group integration should be positively related to the amount of time which the leaders devoted to work in the groups, as well as to their research experience. It was also to be expected that the leader's academic position should have an additional effect; due to a more defined structure of authority, the groups whose leaders held tenure were expected to be better integrated than those headed by younger leaders.

Once again the results of the analysis proved to be disappointing. First of all, the correlations that existed were quite weak. Secondly, the directions of relationships were not exactly those implied in the preceding paragraph. Thus, the amount of time devoted by the leaders to work in the groups tended to have slight (statistically insignificant) negative effect on most of the measures of integration. The research experience of the leaders did seem to have a positive, but slightly curvilinear, relationship to the integration measures (optimum corresponding to 15-20 years of R&D experience). Here again, the

correlations were too weak to be statistically significant. Moreover, the effects of the leader's R&D experience tended to be cancelled out by the fact that, contrary to our expectations, the status of the group leaders appeared to be negatively related to perceived group integration. Thus, the groups headed by junior scientists appeared to be slightly better integrated than those headed by docents, and the latter more integrated than those headed by professors.

So once again, the expectation that the academic status of the leaders influenced group integration positively was contradicted by the empirical findings. Does this mean that there is no significant relationship at all between group integration and leadership? In order to find out, let us examine the relationship between the five measures of group integration and the set of variables measuring the group members' perceptions of the leaders (see preceding section).

Table 13 contains correlations between the two sets of variables. An examination of these correlations indicates that, at least at the level of the members' perceptions, there is a connection between leadership and group integration. (These relations have been explored intensively by Knorr, et al, 1979).

Table 13 Correlations between the perceived characteristics of the leaders and the five measures of intellectual, social and organizational cohesiveness of the groups

Measures of cohesiveness Leaders properties	Coherence of resp. prog.	Participation in plan.	Cooperation	Feeling of belong.	Psych. support
Contact with the leader	.31	.22	.34	.25	.22
Effects of contacts with the leader	.28	.06	.22	.18	.28
Leader's support of the scientist's work	.34	.40	.30	.18	.23
Leadership qualities	.20	.09	.15	.08	.15
Professional abilities	.22	.03	.13	.07	.16
Character	.16	.09	.04	.12	.06
Influence, on the scientist's prob. choice: decision	.35	.09	.04	.12	.06
Influence, on the scientist's prob. choice: support	.23	.10	.32	.25	.47

A closer analysis of the matrix gives useful hints concerning the nature of the data we are using. Let us first ask, which of the perceived characteristics of the leaders seem most closely related to the members' perceptions of group integration? The answer is: the measures reflecting the degree and effect of contacts between the leaders and non-leaders and the degree of support in the relationship leader non-leader. The items such as "leadership qualities", "professional ability", and "character" appear to be almost devoid of importance. This is significant. It suggests that the group members' perception of group climate are determined mainly by their bilateral relations with the leader and relatively little by their judgment of the impact which the leader has on the group process as a whole. Or

to put it differently, the perceived quality of the leader's bilateral relations with the individual group members appears to color the members' perception of group integration.

These facts square well with the results of the sociometric analysis. However, at the same time, they cast some doubt on whether the perceptual variables analysed here and in the preceding section are sufficiently reliable as measures of the impact of leadership on all relevant group-processes. The attitudes of the group members, both to the leader and the group as a whole, are perhaps too strongly affected by their need for psychological support and security. These "emotional" effects may obscure the intellectual and organizational processes which are essential in the analysis of group synergy and performance.

Let us therefore turn to the actual work process in the groups as revealed in the pattern of differentiation of technical roles played by the leaders and the group members.

5. The patterns of differentiation of technical roles in the groups

As we have seen, the group leaders tend to have close collaboration with the large majority of group members. What were the leaders' versus non-leaders' roles in such collaborative relations?

In our questionnaires we included a number of items designed to measure the group members' involvement in various technical functions.^{16/} The items were selected so as to cover all of the more important aspects of the research process. They were:

- 1) Identification and choice of research problem
- 2) Literature review
- 3) Precise formulation of the research problem
- 4) Formulation of hypotheses
- 5) Identification and choice of research methods
- 6) Development of research design
- 7) Data collecting

- 8) Analysis and interpretation of results
- 9) Writing of reports
- 10) Administration.

The correlation among these variables are given separately for leaders and non-leaders in Table 14 & 15. There are no clearly distinct clusters. Rather, in both cases the items form a single elongated cluster. The correlations are strongest among the functions which are nearest to each other, either chronologically or logically, in the research process. For example, "Problem identification" is strongly linked to "Problem precision" and only weakly with "Data collection", which, on the other hand, tends to correlate with "Analysis". This suggests a certain degree of synchronization of the research activities in the groups.

How do the leaders and non-leaders differ as far as their involvement in the research functions is concerned? The answer to this question is given in Chart 20.

Surveying the chart we can distinguish three main groups of functions:

- a) the ones in which the leader strongly dominates; these include the administrative management of the group and the overall direction of the group's research activities;
- b) the ones in which there is a rough balance between the leaders and non-leaders; these include such things as "Analysis", "Literature Review", "Research design" and, to a lesser degree, "Report Writing"; and
- c) the one in which the non-leaders are dominant - "Data collection".

The question is: is this pattern of technical role differentiation common to all the groups or does it vary from group to group? If it varies, what determines this variability?

In an earlier paper it was pointed out that the differentiation in the roles played by leaders and non-leaders, respectively, tends to increase with group size (Stankiewicz, 1979).

Chart 20: Patterns of technical role differentiation in the groups

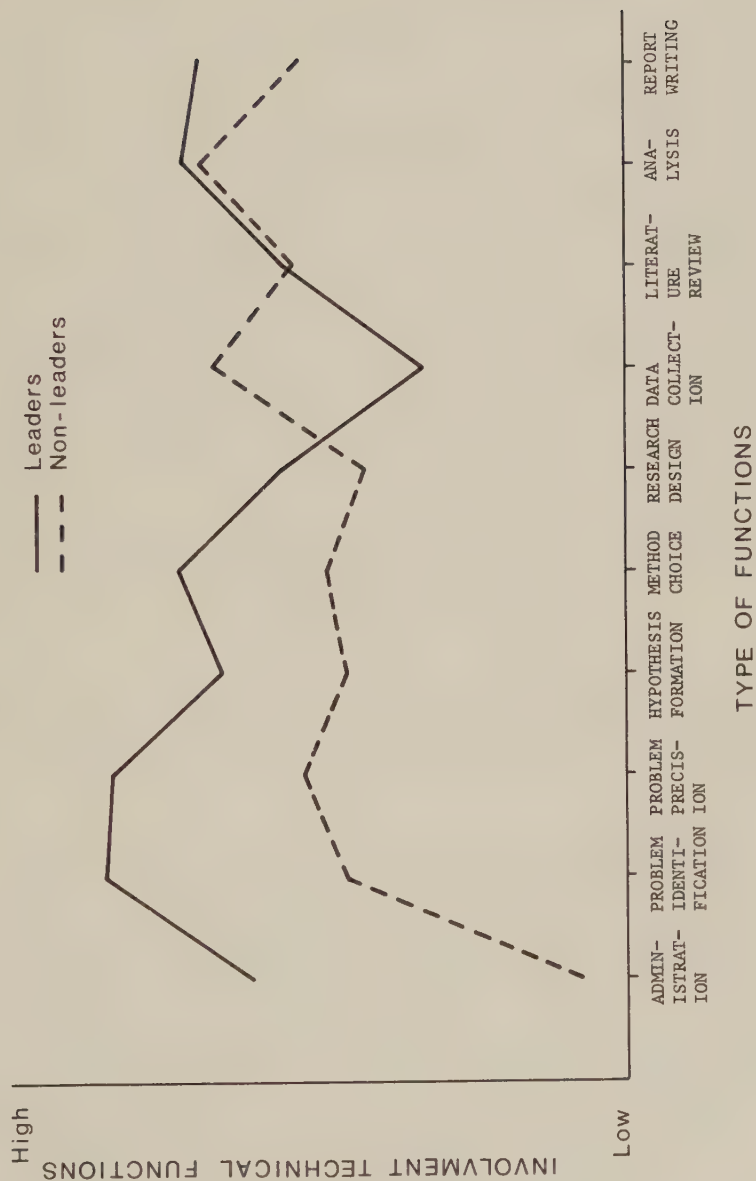


Table 14 Correlations among the elements of the leader's technical role

		1	2	3	4	5	6	7	8	9
Problem ident.	1									
Lit.review	2	.22								
Problem prec.	3	.68	.25							
Method choice	4	.32	.29	.46						
Administr.	5	.37	.03	.29	.04					
Hypothesis	6	.42	.24	.55	.34	.32				
Res.design	7	.37	.14	.42	.38	.35	.48			
Data collect	8	.05	.41	.18	.31	-.09	.19	.24		
Analysis	9	.23	.35	.33	.37	.17	.40	.49	.54	
Report	10	.33	.42	.41	.38	.29	.38	.48	.39	.59

Table 15 Correlations among the elements of the technical roles of the non-leaders

		1	2	3	4	5	6	7	8	9
Problem ident.	1									
Lit.review	2	.38								
Problem prec.	3	.59	.44							
Method choice	4	.33	.24	.50						
Administration	5	.50	.24	.45	.30					
Hypothesis	6	.51	.42	.69	.48	.44				
Res.design	7	.09	.13	.30	.32	.26	.45			
Data collect	8	-.01	.23	.05	.05	.00	.00	.32		
Analysis	9	.26	.24	.28	.11	.27	.26	.36	.68	
Report	10	.45	.46	.47	.26	.38	.54	.25	.16	.36

This agrees well with what is generally known about the relationship between group size and leadership (Carter, 1951 and Hemphill, 1950). There are also other factors on the individual level which are relevant. Thus, the group members who emphasize intrascientific values (such as theoretical interest of the research problems) tend to be more involved in most research functions than the scientists who do not emphasize such matters.^{17/} Jense (1979) has shown that the scientist's involvement in the research functions tends to be affected by his/her research experience and the amount of time spent on research with the group. This is especially important in the case of non-leaders whose involvement in "Administration", "Problem identification", and "Problem precision" increases markedly with their R&D experience. The effects of R&D experience on the levels of the leaders involvement tends to be, on the other hand, almost negligible. The situation is reversed when we consider involvement in research functions in relation to the scientists' "time in the group". The non-leaders' involvement profile seems, on the whole, to be unaffected by the amount of time devoted to work in the group.

On the other hand, time devoted to the group is quite important in the case of the leaders. This, however, applies only to three functions: Data collection, Analysis, and Report writing, all of which tend to be very time-consuming.

The tendencies toward role differentiation confirm what we already know about the central role of leaders. However, our insights into the organization of the groups increase considerably when we look at the effects of the leader's status on the pattern of technical role differentiation in the groups.

Since the academic status of leaders is correlated with the amount of time they devote to work in the groups, one would expect that it should also have some effect on the nature of the role differentiation. This was confirmed in the analysis (reported below), which also revealed several additional facts of crucial importance. The most significant among the latter was the fact that the leader's status appeared not only to affect

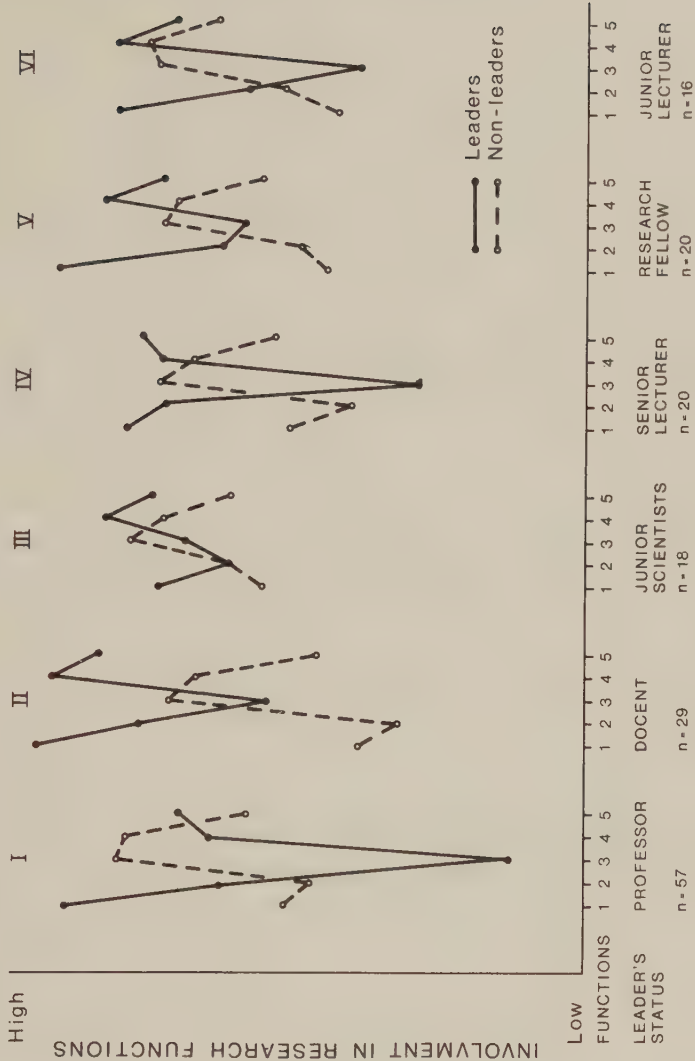
the behavior of the leaders themselves but also that of the non-leaders.

The results of the analysis can best be grasped if we juxtapose the involvement profiles of leaders and non-leaders in the groups headed by scientists with different academic status/employment. Since we are engaged here in univariate analysis, the data could be split into six sets consisting of groups headed by i) professors, ii) docents, iii) lecturers, iv) research fellows, v) junior lecturers and vi) other junior scientists. In order to make the analysis easier to follow the number of research functions was reduced to five: i) Problem identification, ii) Research design, iii) Data collection, iv) Analysis and v) Report writing.

Chart 21 summarizes the results obtained. It indicates the existence of three main patterns of technical role differentiation. These patterns are most visible in the first three diagrams on the chart (the Professor-, Docent-, and Junior Scientist - groups).^{13/} The groups headed by the Lecturers have profiles very similar to those of the Professor-groups. The groups headed by Research Fellows resemble the Docent groups. The Junior Lecturer groups look like a mixture of the Junior Scientist groups and the Lecturer groups -- something which reflects the ambiguous status of their leaders.^{19/}

The differences between the three main patterns of technical role differentiation are quite striking. It is apparent that the roles which the leaders play in their groups vary significantly depending on their academic status. The fact that neither the sociometric analysis nor the analysis of the members' perceptions of group integration gave us any clues as to the existence of such patterns confirms the suspicion that neither of these analysis captured the relevant dimension of the group process - relevant, that is, from the point of view of understanding the synergistic effects. For, indeed, we can see here a very clear correlation between the patterns of technical role differentiation and the presence/absence of synergistic effects in the groups (charts 15 & 16).

Chart 21: Patterns of technical role differentiation given leader's status



FUNCTIONS: 1 - PROBLEM IDENTIFICATION, 2 - RESEARCH DESIGN,
3 - DATA COLLECTION, 4 - ANALYSIS, 5 - REPORTING

Let us consider the three patterns in some detail.

Type I: The groups headed by senior scientists (professors, lecturers) are characterized by strong differentiation between the roles played by leaders and non-leaders. However, this differentiation is not one-sided. The leaders play a clearly dominant role in determining the direction of work in the group; this is understandable given their greater research experience and intellectual authority. At the same time, they seem to be very little involved in the collection of data. This could be interpreted as the result of the leader's power position which may have enabled them to "exploit" the group members. However, it is equally likely that this low involvement in data collecting simply depends on the shortage of time. If so the involvement gap between the leaders and non-leaders should be viewed less as a manifestation of the dominance of the leaders over the non-leaders and more as an indicator of their interdependence. Not able to work with "their own hands", the leaders are forced to work through their groups. This is bound to affect their attitude to the other group members; indeed, if they are to be able to accomplish anything themselves such leaders must catalyze the effectiveness of their group members. This, together with the absence of institutionally induced pressure to demonstrate their individual effectiveness would motivate them to function as the intellectual "spindles" of their groups.

Type II: The groups headed by scientists in the intermediate "limbo" stage of academic career (especially by docents) differ markedly from the preceding category. Although here too we can see strong differentiation between the roles played by the leaders and non-leaders, there is relatively little interdependence between the two role sets. Rather we observe a very strong leader dominance in all the functions except for that of "data collecting". In the latter case we note only a moderate gap in favor of the non-leaders. Equally significant is the fact that, at least in the case of "docent-groups", the very strong leader-dominance is the result of both a very high level of involvement of the leaders themselves and the relatively low degree of involvement of the non-leaders (compare especially the professor

groups with those headed by docents). In other words, we have here a situation involving a hyperactive leader and relatively inactive non-leaders. This could be interpreted as follows: due to the relative abundance of time for research, the docents and research fellows can be relatively self-sufficient even during such time consuming phases of research as "data collecting" and "analysis". Consequently they are less motivated than the professors and lecturers to work through their groups. Furthermore, because they find themselves in an extremely insecure and competitive phase of their scientific careers, they will tend to be relatively egocentric in their relationship with the group. In other words, they will be less likely than the senior leaders to see the group as the main instrument of their own research and more likely to view it as a mere complement to it. It is possible that they, more than other types of leaders, adopt an authoritarian attitude towards the group, or its opposite - namely, complete laissez-faire.

Type III: The groups headed by junior scientists differ radically from the preceding two types in that they, for all practical purposes, lack differentiation between the roles played by the leaders and non-leaders. It is true that such leaders are somewhat more involved than the non-leaders in Problem identification, Analysis, and Reporting. Yet these differences are very minor when compared with the ones occurring in the other types of groups. The impression one gets from studying diagram III is one of "equality" -- the leaders do not differ much from the other members in the group. Thus at least on the technical level, they do not seem to have a special role to play. In fact, the groups headed by junior scientists look like loose aggregates of scientists.

6. Discussion

In this chapter we have tried to explain the effects which the academic status of group leaders appeared to have on the relationship between the performance of research group and their size. The working hypothesis guiding this search was the belief

that the leaders would affect the pattern of integration in the groups and, by extension, the degree of group synergy.

The pattern of group integration was studied by analysing the sociometric structure of the groups, the members' perception of group integration, and the ways in which the technical roles in the group were differentiated and interlinked.

The analysis of the sociometric patterns and the perceptual measures of group integration gave several important insights into the functions performed by the leaders. However, it was only when we turned to the examination of the technical role structure of the groups that significant clues as to the nature of the impact exercised by the leaders on the synergistic processes in the groups were obtained.

Indeed there exists a highly suggestive parallelism between the three main types of effects of group size on research performance discussed in the third chapter of this paper and the three patterns of technical role differentiation described here. The pattern of differentiation & interdependence found in the groups headed by senior scientists (professors and lecturers) seems to provide a plausible interpretation of the strong positive relationship between size and performance found in such groups. The pattern of dominance characteristic of docent groups fits well with our hypothesis about the effects which such leaders are likely to have on group performance. Finally the apparent absence of technical role differentiation in the groups headed by the junior scientists appears to be in agreement with the corresponding absence of any relationship between size and performance in such groups.

These results corroborate the hypothesis according to which the behavior of the group leaders is shaped by the demands imposed on them by the larger academic system. At the same time they can be taken as arguments against a too simplistic interactionist interpretation of group integration.

V. FURTHER EXTENSIONS OF THE ANALYSIS

The analysis reported in chapters two and three suffered from a variety of limitations, the most important of which was the small amount of data. The fact that we can work with at most four subsamples and, then, only by using linear regression techniques is regrettable, since, from the earlier analysis, we know that there occur important curvilinearities in some of the studied relationships. Furthermore we know that there occur among our variables not only two-way interaction but also interactions involving three or, perhaps, four predictors. For instance, it would be interesting to know what happens to the relationship between Group Size and Performance when we control simultaneously for leader's Employment and his Time in the Group. Unfortunately, such an analysis would require more than four subsamples and is therefore not feasible here.^{20/}

However, there is one kind of analysis which, although difficult to perform with our data, is too important to be left out altogether. We have seen earlier that the coherence of the research program (as assessed by the group members) had an important effect on the relationship between Group Size and Performance. In the preceding chapter we saw that research program coherence was relatively independent of the type of group leadership. A question arises: are the effects of the leader's R&D experience on the relationship between Group Size and Performance independent of the degree of coherence of the groups' research programs? What happens, for instance, in a group which has a high level of coherence of the research program and is led by a senior scientist, as opposed to a group which is headed by a junior scientist and also has a high level of intellectual cohesion?

To find an answer, the data was split into four subsamples:

- 1) Groups led by senior leaders (15 or more years of R&D experience) with a high level of intellectual cohesiveness
- 2) Groups led by senior scientists with research programs of low coherence

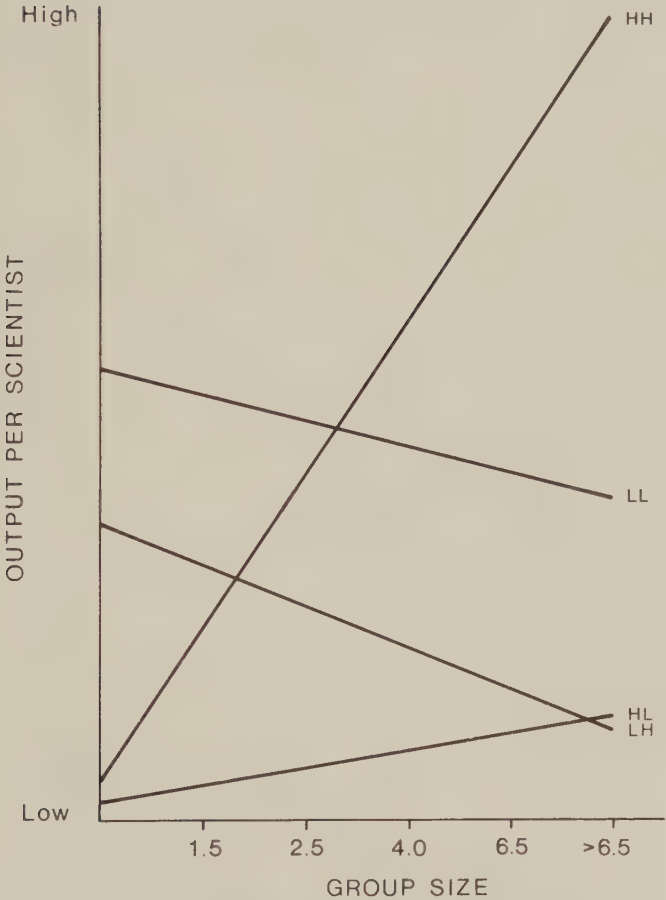
- 3) Groups headed by junior scientists with highly coherent research programs, and
- 4) Groups headed by junior scientist with research programs of low coherence.

The results of the analysis are presented in charts 22 & 23. The tendencies are quite striking. In terms of the quantity of output per scientist the highest correlation between size and performance is found in the case of groups with highly coherent research programs and led by senior scientists. The beta here equals .65. In the remaining cases the correlations between productivity and size are quite insignificant. As far as the index of Recognition is concerned we can see again that the strongest relationship with Group Size exists in the case of groups headed by senior scientists and characterized by coherent research programs. This relationship remains statistically significant even when we control for the effect of total output, which means that both the quantity and quality of output increase with group size.

In the case of groups headed by senior leaders but lacking a highly coherent research program, we can again see a positive relationship between Group Size and Recognition but practically no relationship in the case of Output per Scientist. In such groups there is instead a fairly strong positive relationship between the latter and Group Age ($\beta = .54$). Thus it appears that the advantage of research program coherence in the groups headed by senior consists in allowing them to be highly productive right from the start.^{21/}

In the case of the groups headed by junior scientists, the effects of Group Size and Recognition, over and above those due to the increased total output, are quite negligible (betas equal to .23 in the case of groups with highly coherent research programs and -.22 in the case of groups with low coherence). The general conclusion thus seems to be that while both the coherence of the research program and the properties of leadership are important as the determinants of group-synergy, the latter plays a greater role.^{22/}

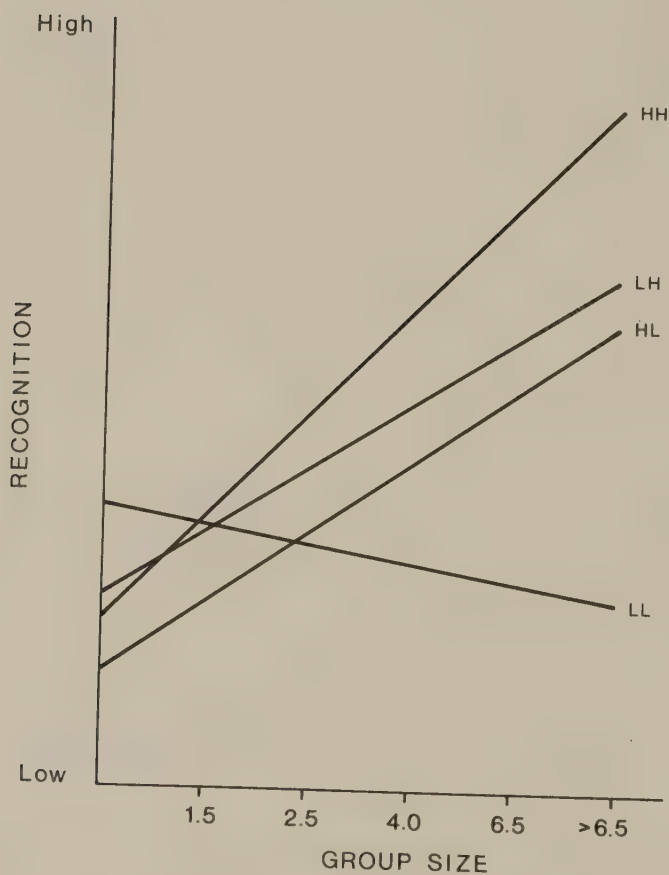
Chart 22: Group Size and Output per Scientist, given the leader's R&D experience and the coherence of the group's research program and controlling for Group Age
(Regression slopes)



	beta	n
(1) HH SENIOR LEADERS + HIGH COHERENCE	+.65**	47
(2) HL SENIOR LEADERS + LOW COHERENCE	+.06	36
(3) LH JUNIOR LEADERS + HIGH COHERENCE	-.19	46
(4) LL JUNIOR LEADERS + LOW COHERENCE	-.10	40

**Sign. at .01 level.

Chart 23: Group Size and Recognition, given the leader's R&D experience and the coherence of the group's research program and controlling for Group Age (Regression slopes)



	beta	n
(1) HH SENIOR LEADERS + HIGH COHERENCE	+.59**	47
(2) HL SENIOR LEADERS + LOW COHERENCE	+.47**	36
(3) LH JUNIOR LEADERS + HIGH COHERENCE	+.39*	46
(4) LL JUNIOR LEADERS + LOW COHERENCE	-.15	40

**Sign. at .01 level

* sign. at .05 level

It would be of great interest to continue this analysis by seeing what happens when the research experience of the group leaders is replaced by their employment. Unfortunately the scarcity of data precludes such analysis. We will have to stop here, fully aware that the explorations presented in this chapter have in no way exhausted all the questions which can legitimately be asked. On the contrary, it is quite obvious that we have only scratched the surface and that the results and interpretations presented above are in no way complete or definite.

VI. CONCLUDING REMARKS

In this study I set out to examine the relationship between the leadership of academic research groups and their scientific performance. The starting point was the belief that research in groups constitutes a synergistic activity in which the interacting individuals reinforce each other's creativity and productivity. The strength of such synergistic effects was thought to be a function of several factors, with leadership being a particularly important one.

In order to test the above hypothesis it was necessary to distinguish between three kinds of effects which the leaders could be expected to have on the performance of their groups: i) the additive effects which reflected the leaders' direct personal contributions to the outputs of the groups; ii) the reinforcing effects which were due to the leaders' influence on the effectiveness of other individual group members, and iii) the synergistic effects which were due to the leaders' ability to promote mutual reinforcements among the group members. Several hypotheses were then presented linking each of these effects to a set of leader characteristics. The most important of these characteristics were: research experience, time devoted to the groups, and employment situation. They were said to reflect the leader's position in the academic career which was subdivided into three broad chronological stages: i) Apprenticeship - the pre-PhD stage, ii) Limbo - the "post-doc" stage, and iii) Tenure.

The examination of the data led to the following conclusions.

a) The additive effects appeared to be related chiefly to the amount of time which the leaders devoted to work in the groups as well as to their positions in the academic system. The influence of the second of these factors was interpreted as being the result of the pressures to demonstrate individual productivity and competence which differ from one stage of the scientific career to another.

b) The reinforcing effects were more difficult to pin-point with any degree of accuracy. They seemed to be related chiefly to the time devoted by the leaders to work in the groups and, with less certainty, to their research experience.

c) The synergistic effects -- which constitute the main focus of this analysis -- were found to be largely unrelated to the time which the leaders spent with their groups. Instead they appeared to vary with the research experience of the leaders and their academic positions. Thus the groups headed by professors and lecturers (Tenure stage of the career) showed strong synergistic effects; the groups headed by junior scientists (Apprenticeship stage) showed no evidence of synergy; and the groups headed by docents and research fellows (Limbo stage) showed signs of negative synergy.

The above results were important, not only because they supported the hypothesis concerning the dependence of group synergy on leader behavior, but also because they established a link between the socio-psychological and institutional aspects of research organization. It was one of my objectives to elucidate the nature of that link. This involved checking the effects which the leader's academic status had on various aspects of group integration: the pattern of communication and collaboration in the groups, the members' perceptions of group cohesion, and the pattern of "division of labor" in the groups.

Contrary to expectations neither the pattern of communication/collaboration in the groups nor the members' perceptions of the group cohesion seemed to be significantly affected by the institutional characteristics of the leaders. However, the examination of these two aspects of group integration did lead to important insights concerning the structure of the groups and the attitudes of their members.

The sociometric analysis of communication and collaboration in the groups shed useful light on the general role played by group leaders. The leaders emerged as the main integrating elements in the groups or, as I also put it, the spindles holding the

groups together. Indeed the level of direct interactions among group members was relatively modest. If anything, our data supported the view that most academic scientists tend to be idiosyncratic and individualistic people who limit intimate collaboration to only a few colleagues. In such circumstances, one cannot hope to maintain a sufficient level of integration among group members (especially in larger groups) by simply relying on their spontaneous gregariousness. Instead what seems to be needed is a catalyzing agent in the form of an active group leader. Such a leader does not so much force the group members to collaborate directly with one another as facilitate the necessary degree of intellectual "correlation" among them. This he might do by functioning as a communication channel, by influencing the work of individuals in the direction of greater convergence, and by providing the group as a whole with a comprehensive intellectual framework which transcends the immediate research concerns of individual members, makes the connections between various aspects of their work more visible, and thus contributes to the natural emergence of common values and objectives.

The degree of success in the performance of such integrative functions will depend on the initial intellectual coherence of the group's research program and the motivations and attitudes of the leaders. If, at the beginning, the research program is very fragmented it may be difficult to promote group synergy, no matter what the leader does.^{23/} If, on the other hand, the leader fails to perform his integrative role the mere cohesion of the research program may not be enough to foster mutual reinforcement among the group members.

In my analysis I found it important to distinguish between the socio-emotional and the intellectual aspects of the relations between the leaders and non-leaders. The former were related to the psychological support which the leaders gave the group members. It is natural that in an activity as unstructured and insecure as scientific research, the sense of getting or not getting psychological support should strongly influence the members' perceptions of group cohesion. However, this socio-

emotional aspect of leadership, while possibly affecting the reinforcement which the individual group members received from the leaders, was not related in a clear-cut manner to group synergy. The latter was found to be linked instead to the intellectual aspect of leadership as reflected in the pattern of "division of labor" in the groups.

The analysis has led to the identification of three main patterns of technical role differentiation in the groups; these patterns correspond to the three main stages of the academic career ("apprenticeship", "limbo" and "tenure"), and, by extension to the three main relationships between the size and performance of the groups.

The first pattern, which is characteristic of the professor-and lecturer-groups, suggests a situation in which the leader, while firmly in charge of the overall direction of the group's work, must depend on the group for the performance of such time-consuming functions as data collecting and -- to a lesser degree -- the analysis. As far as the other functions are concerned, he does not differ much from the rest of the group. It appears that this dominance-dependence situation, combined with the fact that, because of his position, the leader does not have to work under extreme competitive career pressures, creates favorable conditions for his/her functioning as the catalyst of the group process leading to synergy.

The characteristic pattern for the docent and research fellow-groups tells another story. The leader-centeredness of such groups seems rather extreme. The overall level of involvement of the non-leaders is here clearly lower than it is in the groups headed by professors. Thus it seems that, in so far as the leader plays an integrative role, he does so at the cost of restricting the scope of activities of his fellow researchers. Such a hyperactive, and perhaps egocentric, leader achieves a high level of individual productivity, but finds it difficult to maintain a similar level of performance in the group as a whole -- which shows up with increasing clarity as the groups grow larger.

In the pattern which is characteristic of the junior scientist-groups, the role differentiation is hardly visible. Evidently, the differences in status among the members are too small for the leadership structure to emerge in a real, rather than purely formal, sense. This absence of leadership accounts for the lack of synergy in the groups which behave as if they were simply aggregates of scientists.

* * *

Even if the above results must be treated with caution - I hope this was made clear in the preceding chapters - they are quite suggestive and should provide a good point of departure for a broader discussion of certain aspects of the academic system. This is not the place for such a discussion, but a few general observations are in order.

Academic research, at least in the natural sciences and technology, has become a predominantly group-based activity. Consequently the features of the academic system which affect the organization and performance of research groups have acquired special interest. In fact, the question of the overall research effectiveness of universities cannot be satisfactorily answered without assessing the degree of consonance between their organization and the requirements of effectiveness of research groups.

We saw that the effectiveness of groups is strongly affected by their leadership and that leadership is strongly affected by the academic career system. It is therefore interesting to know just what proportion of academic scientists, who are group members, work in groups led by scientists who promote group synergy and/or reinforce the effectiveness of individual members.

Table 16 indicates the proportion of scientists surveyed by us who worked under different types of leaders.

Table 16 Estimated proportions of scientists working under
different types of leaders

Type of group leader	% of scientists (group members)
Professor	41
Lecturer	11
Docent	21
Research Fellow	12
Extra lecturer	6
Junior scientists	<u>9</u>
	100

Very roughly we may say that 50% of scientists belong to groups headed by senior scientists, less than 40% to groups headed by scientists at the intermediate stage of the career, a little over 10% to groups headed by junior scientists.

The fact that so large a proportion of the researchers work in groups headed by leaders at the first two stages of their career must, in the light of our results, be viewed as problematic. Even though many such leaders (especially docents and research fellows) head relatively small groups (in which case the reinforcement effects of leadership might have more than compensated the absence of synergistic effects), it is possible that we have here a source of inefficiency in the Swedish academic organization. It must be added, however, that also the small groups headed by the senior scientists appear to be problematic.

Assuming that the proportion of groups headed by docents, research fellows, and junior scientists is too high, what can be done about it? The most obvious solution would be to shorten the "limbo" stage of the academic career and to increase the number of leaders with tenure. The academic pyramid - with a relatively broad base and very few top positions - may have been functional when university research was an individualistic activity. As our study indicates, however, that is no longer the case. Consequently there is today a need for a larger stratum of senior

scientists who, no longer hampered by the problems of academic survival, can devote their energies to effective management of research groups. It will be interesting to see whether the recently carried out or planned reforms of the Swedish academic career will help to bring this situation about.

* * *

Finally, let me comment briefly on one question which will inevitably arise in the reader's mind: what about the "lonely wolves" of science? Isn't there an implication in the conclusions of this study that the time of the soloist is over, that without the benefits of "reinforcement" and "synergy" the researcher cannot hope to progress far in contemporary science?

I think we should be very cautious about drawing such categorical conclusions. After all, we did not study the performance of group members in comparison with that of pure individualists. Personally I feel quite sure that there are many brilliant and productive scientists who perform best when left entirely on their own. However, I doubt whether they constitute a majority. On the contrary, the prevalence of group-based research, especially in the so-called hard sciences, indicates that the advantages of such organization are real and widely recognized. One thing more. I do not feel that group-based research - at least of the kind that we have studied here - constitutes a threat to the initiative and creativity of individual researchers. In fact, we saw that few group members were involved in intimate collaboration with many colleagues. It appeared rather than research in academic groups tended to be segmented on an individual or quasi-individual basis. This is quite natural given the fact that many of the group members work on their PhD dissertations; it is also consonant with the individualism of the academic ethos. Thus, I think that the main difference between group-based research and purely individualistic research is not that the former is uncompromisingly "collective" while the latter is the opposite. Rather it consists in the fact that in research groups individualism is kept in bounds so that the group members can benefit from each other's effort. The fact that "personal interest" rated, after "education", as the second most important fac-

tor influencing the group members' direction of work indicates clearly that belonging to a research group did not imply intellectual oppression of any kind. In fact I see no serious conflict between group membership and the traditional scientific role -- as far, that is, as the non-leaders are concerned. Such a conflict arises first when a scientist makes the transition to the role of leader.

NOTES

- 1) A shorter account of some of the main results presented in this report have been published earlier in R&D Management 9, Special Issue, 1979.
- 2) The parallel use of quantitative and qualitative (judgemental) performance measures is meant to provide our analysis with an extra validity check. Should the results involving these two measures differ strongly their reliability would have to be considered as questionable. The reason for this is that many past studies have shown that the quantitative and qualitative measures of performance tend to go together (see, for example, Cole & Cole, 1973). See also, note 3, below.
- 3) Here we must compare the signs and relative steepness of the regression lines (or MCA curves). Additional information can be derived by checking whether Group Size makes a significant contribution to the explanation of the variation in Recognition when we control for the effects of the total output of papers. The rationale for this procedure is that, while Recognition is a function of the total output of papers, the increase in the latter does not necessarily reflect an increase in per capita productivity. If, in the case of no relationship between Size and Output per scientist, the positive correlation between Size and Recognition persists after the effects of the total output have been controlled for, it is still possible to assume synergistic effects underlying the correlations. If, in the case of a positive relationship between Size and Output per scientist, the correlation between Size and Recognition disappears after the effects of the total output have been controlled for, it is also possible to assume the existence of synergistic effects. If both relationships are positive, we have strong evidence for such effects. If both relationships are negative or neutral, we have strong evidence against the occurrence of synergy. When the two relations have opposite signs, we have an inconclusive result. This last situation has occurred only once in may analyses och involved two weak, statistically insignificant relationships; there was therefore no evidence for synergy.

4) As a measure of the cohesion of research programs, the number of projects proved clearly inferior to the perceptual measures used here. The two kinds of measures produce a similar pattern of correlations with other variables, but, in the case of the perceptual measures, these correlations are stronger. The superiority of the perceptual measures may depend on the fact that in many cases "projects" constitute administrative, rather than intellectual, entities.

5) It is often pointed out that the importance of leadership increases with group size (compare Hare, 1976; Berelson & Steiner, 1964; Carter, 1951; Hemphill, 1950). This accounts for the often observed progressive differentiation of the leader role and a corresponding increase in the demands placed on the occupant of the role by other group members. An individual's willingness to accept such demands will be largely determined by the nature of other roles which he/she is expected to perform. My assertion is that the academic roles associated with different stages of the scientific career may be more or less consonant/dissonant with the role of group leader. The effect of role dissonance should be felt more acutely as group size increases.

6) The distinction between these two leadership functions can be so great that they might become divided between different group members (comp. Hare, 1976). Our data did not permit any examination of such effects.

7) The literature on the leadership of research groups is very limited indeed; among the few items which have some relevance for our analysis we can mention Hagstrom, 1965, Ch.III and 1967, Lemaine, et al. 1972, Pelz and Andrews, 1976, Ch.2 and 12, and Knorr, et al. 1979. None of these, however, deal directly with the relationship between leadership and group synergy as defined here.

8) In the terminology adopted here "research fellow" corresponds to what is called in Swedish "forskarassistent" - a research position occupied, as a rule, by a person who holds a PhD degree (see note 9 below) but who has not yet acquired the

qualifications of a docent (associate professor). "Junior lecturer" corresponds to what is called in Swedish "extra universitetslektor" - a teaching position without tenure. The "junior scientists" hold either stipends or various assistantships.

9) The "new style" Swedish doctorate corresponds rather closely to the American PhD. The "old style" doctorate - no longer awarded - required a dissertation of a considerably larger scope. "Licentiate" is a scientific degree with requirements somewhere between the American Master's and PhD degrees; as with the "old style" doctorate, the "licentiate" is no longer awarded.

10) The word "roughly" should be emphasized. Even if we accept the view that the leader of a group constitutes its "first member" -- which seems reasonable enough -- it must be remembered that both the slopes and the points of origin of the regression lines might be affected by non-analyzed curvilinearities of the underlying relationships. (Also it might be argued that one should use as the indicator of leaders' productivity the point corresponding to group size which is equal to one rather than zero. However, even if this would be more correct it would not change any of our substantive conclusions).

11) When the total output of papers is controlled for, the marginal effect of group size becomes insignificant. See also note 3 above.

12) The most extensive studies of the effects of interaction on individual research performance have been conducted by Pelz & Andrews, 1976. They found that, generally speaking, the higher the frequency of contacts and the larger the number of persons contacted within the research group the higher the performance. Unfortunately, for methodological reasons, these results cannot be directly compared with the ones presented in this report.

13) This means that our indices of communication were based on judgemental, that is subjective data. Use of such data is not without risks. However, in order to generate fully acceptable

quantitative indicators we would have to devise a large and very complicated battery of questions - something that would further inflate the size of our already voluminous questionnaires. The same is true for some other variables used in the present analysis, especially those measuring group cohesiveness.

14) The leader's influence, as manifested in his/her power to make decisions that are binding on individual members, is one of the most important factors affecting the direction of work of the members (compare Table 4). It is interesting, therefore, that it should stand as a separate dimension. The variable is related to the perceived cohesion of the group's research program and a few additional variables. Of the latter, the most significant is the perceived degree of influence exercised over the group's research program by its financiers ($r=.35$). This suggests that the external pressures on the group affect the style of leadership and, by extension, its organization.

15) The measures had the form of five-point ordinal scales.

16) As above.

17) This implies that in the groups whose members are strongly motivated by the intrascientific values there is both a very high general level of participation in all functions and a relatively low level of differentiation between the leaders and non-leaders.

18) These three types of groups constitute over 60% of the sample.

19) This ambiguous category represents less than 10% of the sample.

20) Neither could we introduce "research field" as a control variable. This was regrettable since there are hints in the literature that the importance of group size may differ from speciality to speciality (comp. Blume & Sinclair, 1973b).

21) Compare also with the effects of other measures of group cohesion reported in Stankiewicz, 1979b. Generally speaking, when the groups are cohesive there seems to be very little relationship between their "age" and performance. In such groups, size is a far more important factor. In the groups lacking cohesion, on the other hand, the importance of group size decreases while that of group age increases. Thus it would seem that the less cohesive groups might reach quite high levels of per capita performance but only after a relatively long period of time. The highly cohesive groups, on the other hand, can quickly reach similar levels of performance simply by increasing their size.

22) Here we should make one additional reservation. It seems that the degree of cohesion of the groups studied was generally high (compare chapter two, section 1.4). So perhaps there is too little difference between the groups which here are characterized as "highly" cohesive and those whose cohesion is described as "low". We would be on safer grounds if we could isolate the groups with very low cohesion. Unfortunately there are too few such groups in our material.

23) Concerning the necessary degree of coherence of the research program, it seems to be a good rule of thumb that the members of the group should be able to understand and follow with interest the technical details of each other's work. This does not mean that we deny the value of interactions between scientists who strongly differ in their intellectual interests. On the contrary, such contacts are crucial in order to avoid intellectual inbreeding; therefore the creation of large departments with many research groups as well as other measures promoting contacts among specialities and disciplines appears to be desirable. However, the special function of a research group is to create the environment in which a scientist can discuss his work in depth and continuously, rather than generally and sporadically.

The International Comparative Study on the Organization and Performance of Research Units

1. The background and history of the project

The Swedish sample of research groups analysed in this report constitutes a part of a larger set of data collected in the course of the International Comparative Study on the Organization and Performance of Research Units. The International Study has been initiated and coordinated by UNESCO. The main reasons which caused UNESCO to undertake the study were:

- the recognition of the fact that scientific research, both applied and basic, has become predominantly a group-based activity;
- the realization that the group level of research organization had not been previously studied to any significant extent, and
- the belief that rapid progress in this neglected area of the sociology and psychology of science could best be promoted by stimulating international research cooperation.

Work on the project started in 1971 with the establishment of the International Research Team which begun exploring the theoretical and practical aspects of the project. The team consisted of researchers from the participating countries, some members of the staff of UNESCO's Division for Science and Technology Policies, and a number of external consultants. Prof. Frank M Andrews, Institute of Social Research, University of Michigan, and Nicole Visart of UNESCO played central roles in the scientific and organizational coordination of the project.

The study progressed through three main stages:

- 1) Early methodological development which centered on identifi-

cation of the main analytical concepts around which the study was focused, their "operationalization" for the purpose of data-collecting, and a field test on 20 research groups in four countries (Austria, Belgium, Spain and Sweden).

- 2) Advanced methodological development in which all the aspects of the methodology (from sampling procedures, through actual data collecting, to identification and testing of appropriate statistical techniques) were examined. This was done in 1972 in the course of the so-called Alpha-test which involved collection and analysis of data from 150 research groups in Austria, Belgium, and Sweden. On the basis of this test the final methodology of the project was worked out.
3. The First Round Survey which represented the first massive application of the methodology involved a survey of over 1200 research groups in six countries (Austria, Belgium, Finland, Hungary, Poland and Sweden). The data collection was carried out in 1974. The analysis was executed in the following years culminating in the publication in 1979 of a collective scientific work summing up some of the most important results from the study (Andrews, ed. 1979).

The International Study has now progressed to the next stage (the Second Round) in which the survey is extended to new countries including India, Argentina, Egypt, Rep. of Korea and the UkSSR).

2. The general approach

The approach evolved by the International Study reflects both its immediate theoretical and methodological concerns and a certain philosophy of social research. The latter could be summed up as follows: The slow growth of social knowledge is, to a considerable extent, due to the lack of coordination of the research efforts carried out by individuals and groups in different countries. This is reinforced by the absence of theoretical consensus, especially in new fields. In order to break

this vicious circle, massive collaborative research should be stimulated. Joint research would stimulate dialog among various schools of thought, create a common cumulative research base, and eventually help to develop some degree of theoretical consensus leading to new, hopefully more fruitful, undertakings. The International Study can be viewed as an application of this philosophy. It is conceived as a long range international activity. Starting practically from "scratch" it proposes to create a whole research specialty by carrying out a succession of surveys, each of which builds on the experience generated in the previous ones and expands both the theoretical and empirical basis of the collective undertaking.

A project of the sort envisaged here constitutes a difficult experiment. It must be realized that the International Study is not only the largest study of research groups ever undertaken, it is also one of the largest surveys of organizations of any kind. It is therefore not surprising that its basic approach was theoretically eclectic and methodologically tentative.

The participants in the project agreed that, given the desire to create a cumulative body of comparable data, a quantitative statistical approach was appropriate. It was also agreed that the data collected should be heterogenous in the sense of representing research groups from different research fields, institutional backgrounds, and countries. This heterogeneity was deemed necessary both from the theoretical point of view (the comparative aspect) and in order to make the project attractive to the largest possible audience of social scientists and research managers.

The heterogeneity of the sample automatically implied the necessity of a very comprehensive set of data both in terms of the sample and the variables studied. This tendency towards comprehensiveness has been reinforced by the absence of a single generally accepted theoretical framework which could guide the choice of relevant variables and their operationalization. It was agreed that, at least during its early stages, the project should be very eclectic in its choice of variables to be studied

and follow a wide range of theories drawn from the sociology of science and the social psychology of organizations. One of the main premises of the project was that in its successive stages the fruitless variables would be weeded out and, where appropriate, be replaced by more relevant ones.

The heterogeneity of the data and the theoretical open-endedness of the approach, while probably necessary in a project such as this, have brought with them special difficulties. The desire to obtain data from many different scientific environments led, paradoxically, to difficulties in adequately describing them. It proved impossible to devise data collecting tools which would work satisfactorily in so many different national and institutional environments. The consequence of this has been a bias in favor of the social-psychological aspects of group organization at the expense of the institutional analysis. Similarly, the desire to include in our survey groups from many different fields of science meant that our ability to describe adequately the scientific content of their work decreased significantly. This made analysis of the intellectual process in the groups difficult.

The absence of a full theoretical consensus among the participants in the project was another problem. The questionnaires which have been developed were the outcome of intellectual "bargaining" involving a variety of scientific, organizational and national interests. Given the poor development of theory in the field such bargaining was unavoidable and not necessarily detrimental to the study. But it had one serious disadvantage: the questionnaires used have grown much larger than they would have been if they reflected a single coherent scientific perspective.

3. Questionnaires

The data about the groups studied was obtained with the help of fully structured questionnaires administered in the course of group interviews to the group members and, by mail, to a number of external observers.

Five distinct kinds of questionnaires were used; each consisted of a core of questions common to the International Study as a whole, and a smaller number of additional items added by national teams to the questionnaires to be used in their countries only. The content and function of the five types of questionnaires were as follows:

1) The RU questionnaire, directed to the group leader or its administrator focused on 90 core variables divided into the following headings:

- A. Identification of the group
- B. Facilities at the disposal of the group
- C. Training and career development facilities
- D. Human and financial resources
- E. Administrative delays

The Swedish version of the questionnaire contained, in addition, the following kinds of variables:

- F. Size and structure of the group's financial resources
- G. Size and structure of the department to which it belonged

2) The SA questionnaire, directed to the group's leader, focused on 230 variables divided into the following headings:

- A. Leader's individual profile (personal background data, individual productivity, etc)
- B. Renumeration and advancement
- C. Activities and tasks performed (including time budget)
- D. Methods used in research work
- E. Scientific Fields and Research Projects in the group
- F. Scientific Exchange of the group
- G. Evaluating the work of the group (accuracy, frequency and nature of evaluation procedures)
- H. Choice of research themes
- I. Working climate
- K. Evaluation of budget, facilities and services available
- L. Patterns of influence in the group
- N. Organization and Planning of the research work
- Q. Contacts with other groups

- R. Products of the group
- S. Application of results obtained by the group
- T. Value of the work of the group

The Swedish version of the questionnaire contained in addition the following groups of variables:

- U. Academic qualifications and employment of the respondent
- V. Respondent's attitude towards the group
- W. Factors affecting the respondent's direction of research in the group
- Z. Patterns of collaboration in the group

3) The SB questionnaires directed to the other professional members of the groups focused on a set of variables almost all of which were identical with those included in the SA questionnaire except for three sets: F, G and H which were eliminated in the SB version. The latter contained, on the other hand, an additional set of items (X) measuring the group members' perception of the leader.

4) The TS questionnaire directed to the technicians of the group constituted a sharply reduced version of SB questionnaires; as compared with the SA questionnaire it contained only sections A, B, I, and X.

5) The EV questionnaire directed to external evaluators of the groups' scientific performance is described in detail in Appendix C. This questionnaire contained a set of only 11 variables.

There were one RU and one SA questionnaire per group. In the case of SB, TS and EV questionnaires there were, as a rule, several respondents per group. In the latter case group level variables were derived from individual responses by averaging them in a suitable manner, and/or by calculating various dispersion measures.

The group level data file based on the five questionnaires consisted of over 600 primary variables. These variables have been in turn used to build a variety of secondary measures/indices.

The number of variables in the study is rather staggering. It is therefore important to note that the volume was, to a large extent, the result of using multiple measures for concepts which were difficult to operationalize. However, the eclectic nature of the approach has been the primary cause of the complexity of the questionnaires.

The Swedish team participated in the development of the questionnaires and shares the responsibility for their final form. However, as already pointed out, the questionnaires were the result of compromise which required the participating teams to give up some of their ideas and wishes. The members of the Swedish team felt that the questionnaires contained too few indicators of the institutional situation of the studied groups, pattern of collaboration in the groups, the factors affecting their direction of work, and the nature of social-psychological ties holding the groups together. We have also felt that it was important to have some more data describing the tangible aspects of group structure even at the expense of some attitudinal data. We do feel, however, that we have managed to restore the balance in the questionnaires by adding certain items to the Swedish version of the questionnaires. These additions proved to be of decisive importance for our analysis.

4. The data

A "research group" or, as it was also called, "research unit", was defined for the purposes of the study as a set of individuals working under common intellectual leadership in a well defined research area. According to the standard Unesco definition, the minimum number of group members was set at 3.

Using the above definition, the populations of research units were identified and their samples drawn in each participating country. (The details of the Swedish sampling procedures are given in Appendix B). Due to the divergence of theoretical and practical interests, it was not practical to aim at identical sampling plans in all the participating countries. Consequently

a more modest objective of securing partial overlaps of the national samples was adopted. This meant that, for each combination of research field and institutional environment, there should be data available from at least two countries. This objective was, by and large, fulfilled.

The International Data File which resulted from the above mentioned sampling procedure consisted of 1222 research groups. The breakdown of the total sample by country, type of institution (organization) and scientific field is given in Table A1.

The International Data Set must not be regarded as a sample representing some well defined single population. Instead it should be viewed as a data pool consisting of representative subsamples of specific populations of research groups in a few European countries. The extent of the differences in the sampling plans in the participating countries can be seen in Table A2 which gives the distribution (percent) of research groups by type of institution and country. Note, for instance, that while the Swedish subsample consists solely of academic groups, only 32% of the Finnish sample belong to this category.

Two of the participating countries (Hungary and Sweden) had separate national subsamples which were larger than those incorporated in the International Data Set. This was due to the fact that these two countries used somewhat more inclusive criteria for defining the research group populations than the ones established by Unesco. Thus the Swedish national sample consisted of 172 groups of which only 152 were incorporated in the International Data Set. The difference (20 groups) was due partly to delays in data collection, and partly to the fact that our version of the definition of research group set its minimum size at two instead of three members (for discussion of the Swedish sampling procedures see Appendix B).

The International Data Set corresponding to 1222 research groups has been, after necessary checking and "cleaning" of the data, transformed into a standard International Data File containing over 1200 primary and secondary variables both on the group

Table A1 Distribution of the Round 1 research groups by country, by type of organization and by scientific field

Countries	N	%	Type of organization	N	%	Scientific field	N	%
Austria	244	20	Academic organizations	694	57	Mathematics	13	1
Belgium	193	16	Academies, etc.	45	3	Astronomy	6	-
Finland	219	18	Cooperative organizations	257	21	Physics	77	6
Hungary	222	18	Productive enterprises	217	18	Chemistry	240	20
Poland	192	16	Private institutions, etc.	9	1	Life sciences	215	18
Sweden	152	12	Totals	1222	100	Earth, space sciences	69	6
						Agricultural sciences	125	10
						Medical sciences	57	5
						Technological sciences	345	28
						Social sciences	75	6
						Totals	1222	100

Table A2 Distribution (percent) of Round 1 research groups by typology and country

Typology	Austria	Belgium	Finland	Hungary	Poland	Sweden	Total
1. Academic organizations, exact and natural sciences	33	46	18	42	24	80	39
2. Academic organizations, medical and social sciences	0	27	0	10	20	0	9
3. Academic organizations, applied sciences	14	11	14	8	16	20	14
4. Cooperative organizations, various sciences	11	5	34	26	40	0	20
5. Productive enterprises, applied sciences	37	11	34	14	0	0	18
Total	100	100	100	100	100	100	100
Number of groups	(244)	(193)	(219)	(222)	(192)	(152)	(1222)

level on the level of individual responses. The file which exists in two versions (OSIRIS and SPSS) is available to interested researchers. Copies can be obtained from the Belgian Archives for the Social Sciences, Louvain.

5. Analysis

The analysis of the data was left to the discretion of the individual research groups of the International Team although some care was taken to prevent unintentional duplication of work. Furthermore, even if no attempt was made to impose a single analytical strategy on everyone, the participants agreed to develop and use certain common measures and indices. This was necessary in order to make the partial results easy to compare. Special care was taken to develop a common set of procedures for measuring the performance of the groups.

The absence of a single common plan for analysis did not mean the absence of cooperation. On the contrary, throughout the whole period of analysis, there occurred important bilateral and multilateral exchanges and collaborations concerning both theoretical and methodological issues.

The participating research teams had two main strategies to choose from: (i) to work with the entire international data set using such variables as country, field, and type of institution as controls, or (ii) to work with separate homogenous subsamples. As an example of the first of these approaches, one may take work carried out by the Austrian team, while the second approach can be exemplified by the work done in Sweden. The choice between the approaches depended mainly on the specific interests of the researchers. The two approaches are of course complementary.

Among the major topics tackled by various analysts the following ones should be mentioned as especially important:

- Individual vs. group productivity
- Relationship between group membership and individual acade-

mic career

- Patterns of influence in the groups
- The material resources of the groups
- Effects of leadership on group performance
- Effects of group size and age on performance
- Research planning & management techniques
- Communication between and within the groups
- Individual motivations vs. group performance
- Patterns of intragroup coordination
- Interdisciplinarity and research groups

Among special methodological issues explored in detail were:

- Measurement of research performance of groups
- Empirical typologies of research groups
- Sampling procedures and strategies
- Construction of group-level indicators from individual-level-data.

The above lists should suffice as illustrations of the potential fruitfulness of the eclectic approach adopted by the International Study.

Up to now the analytical efforts mentioned above have resulted in two major publications (a collective scientific book under the title "Scientific Productivity" and edited by F. Andrews, and vol. 9 of "R&D Management" - a special issue) as well as a series of special reports and individual journal articles. The analytical effort has by no means terminated. Indeed, much more is to be expected, especially after the completion of Round Two of the project now under way in several additional countries. It is therefore not an exaggeration to say that the International Study has inaugurated a rapid growth of literature in this until recently neglected area in the sociology of science.

6. The Swedish participation in the project

Sweden participated in the Unesco project almost from its first days. Originally the team consisted of B. Nordbeck and R. Stan-

kiewicz at the Research Policy Programme in Lund. In 1973 B. Nordbeck left the team and was replaced by G. Jense. The scientific director of the project in Sweden was R. Stankiewicz. The Swedish participation in the project was sponsored and financed by FEK committee of the Swedish Research Council for Natural Sciences. G. Friborg of FEK functioned as the Swedish National Liaison Officer of the project.

The specific nature of the Swedish involvement in the Unesco project was a result of various scientific and practical considerations. The special theoretical interests of the Swedish team have already been mentioned. They have led to various additions to the Unesco's core questionnaire thus making it necessary to construct a special Swedish data file. The need for a special file was further reinforced by the special features of the Swedish sample.

Compared with the other countries participating in the International Study, Sweden produced a very homogenous sample in terms of institutional setting. All the groups surveyed in Sweden were academic and, in addition, were drawn solely from natural sciences and technology. There were two main reasons for such a design: statistical and economic. We suspected that institutional variables would strongly affect the relationships under study, and that the data would therefore have to be split into several subsamples. Such subsamples could easily become too small for meaningful statistical analysis. It was much safer to work with a relatively large homogenous sample. Furthermore, during the Alpha test we learned that the more heterogenous the sample the greater were the costs of data collecting. This again favored a homogenous sample.

The particularities of the Swedish sample made it natural to analyse it separately. However, the main reasons for following this course were theoretical. In the analyses that we planned to carry out the institutional factors and the variables describing the groups' structures were of crucial importance. Most of these variables existed only as additional items in the Swedish questionnaires.

The analysis in Sweden was carried out along two district lines.

(i) G. Jense analysed the data at the respondent level focusing on the effects which the Swedish academic system had on the behavior and attitudes of the individual group members. His work had some parallel to certain analyses carried out by the Austrian team.

(ii) R. Stankiewicz analysed the data at the group level concentrating chiefly on the effects of group size and leadership on scientific performance. This analysis was also in some respects similar to that conducted in Austria (see Andrews, ed. 1979).

So far, the work of the Swedish team has resulted in the following reports and publications:

Stankiewicz, R - Research Groups and the Academic Research Organization, Sociologisk forskning, Vol XIII, no 2, 1976

Jense, G and Stankiewicz, R - Forskargrupper vid de matematisk-naturvetenskapliga och tekniska fakulteterna - RRV, Stockholm, 1976

Jense, G - The Swedish Academic Marketplace - doctoral dissertation, Lund, 1979

Stankiewicz, R - The size and age of Swedish academic research groups and their scientific performance, in F. Andrews, ed. Scientific Productivity, Cambridge University Press/Unesco, 1979

Stankiewicz, R - The effects of leadership on the relationship between the size of research groups and their scientific performance, in R&D Management, vol 9, (Special issue), 1979

APPENDIX B

THE SAMPLE

For the purpose of our study a research group was defined as "a group of scientists (at least two) working under common intellectual leadership in a well defined research speciality. The members of the group engage in continuous or periodic research collaboration. The leader is an active researcher in the group. A scientist may belong to more than one research group. The members of the group may be recruited from two or more formal units/organizations".

The above definition deviates from the standard Unesco definition in that it sets the minimum group size at two instead of three members. The deviation was the result of our experience during the pilot study (the Alpha-test) which clearly indicated that, at least in the Swedish academic setting, the exclusion of two-person groups would be quite arbitrary.

Due to this divergence from the standard Unesco procedure, the Swedish team devised two partly overlapping samples of research groups, in one of which the two-person groups were left out.

Our definition of "research group", which has been worked out in the course of extensive pilot studies, emphasizes the essentially non-formal character of such groups; they may, but need not, correspond to the official organizational subdivisions of academic departments or industrial laboratories. As could be expected, reliable lists of such informal entities are hard to come by. In fact we were forced to generate such lists as the first step of our sampling procedures.

The population to be covered by our survey was defined as "the research groups at the faculties of natural science and technology at the Swedish universities and technical high-schools". This restricted definition of the population was motivated by both theoretical and practical concerns. As noted in Appendix A we learned during the pilot study that the costs of sampling

and data collection tended to increase rapidly with the institutional heterogeneity of the sample. Moreover, we calculated that the increases in the heterogeneity of the sample would require a significant increase in the size of the sample. Given the fact that our resources did not permit a sample larger than 200 research groups, we decided to concentrate on a relatively homogeneous population.

The sampling procedure consisted of two stages: 1) the sampling of academic departments at the Swedish faculties of natural science and technology, and 2) the sampling of the research groups within each of the selected departments. This amounts to a two stage cluster sample.

The first stage of the sampling process was executed as follows (see also Stankiewicz, 1976): A list of all the departments (institutioner) and divisions (avdelningar) of the faculties of natural science and technology was prepared. Whenever a department consisted of two or more divisions, the latter were used as the sampling units. This list was used to draw a random sample of 170 departments/divisions, corresponding to 55% of the total population. To each of these 170 departments/divisions a questionnaire was sent containing the definition of "research group" and asking for a list of such groups in the department/division. The respondents (the heads of department or persons designated by them) were asked to indicate the degree to which each of the listed groups satisfied our definition; the alternatives were: "completely", "by-and-large", and "marginal case". The response rate to the survey was satisfactory: 80%.

No systematic bias could be detected. Only in a few cases did our respondents object to the definition in the questionnaire.

The 136 departments/divisions which answered our questionnaire were found to contain 478 research groups, which gives an average of 3.5 groups per formal unit. However, the number of groups per department varied greatly. Over 20% of departments/divisions had no research groups at all while nearly 10% had 8 groups or more.

The identified groups appeared to fit our definition quite well -- only 10% of them were regarded as marginal cases. Some of these could be dropped from our list immediately, reducing it to 460 groups.

The second stage of the sampling procedure was executed as follows: Each of the departments/divisions selected during the first stage of sampling constituted a cluster of research groups. The clusters were unequal in size. To compensate for that, the individual research groups selected at the second stage were sampled with probabilities proportional to the size of clusters to which they belonged.

The second stage resulted in a sample of 230 groups. We decided to have more than 200 groups since we anticipated that, upon direct examination, some of them would be found to deviate too much from our definition while some others might prove impossible to survey for other reasons.

Of the original sample of 230 groups only 172 were surveyed. Of the 58 groups which were lost, however, only 30 can be viewed as "drop-outs" proper. The remaining 28 groups proved upon direct examination either not to exist (they disintegrated in the time following the sampling survey or were listed by mistake) or did not fit our definition at all. So the true drop-out rate at this stage was 14%. Of these about half was due to a refusal to participate in the study and half to practical difficulties (usually because the groups were temporarily dispersed during the time of our survey) making data collection impossible.

The cumulative drop-out rate for both stages of the sampling process can be estimated at around 31%. This is significant but by no means fatal considering the fact that at no stage did we observe any biases in the drop-out rates. Hence, the sample which has been obtained can be considered as quite representative of the population. The table below gives its composition in terms of fields and faculties.

Table B1 The composition of the sample

Field Faculty	Formal sciences	Physics	Chemistry	Biology	Earth & Space	Engineering	All
Natural sc. faculties	8	19	22	43	9	--	101
Technology faculties	6	18	11	--	3	33	71
All	14	37	33	43	12	33	172

APPENDIX C

THE PERFORMANCE MEASURES

This appendix consists of two parts, the first dealing with the so-called "rated performance measures" and the second with the quantitative output measures.

PART I: Rated Performance Measures

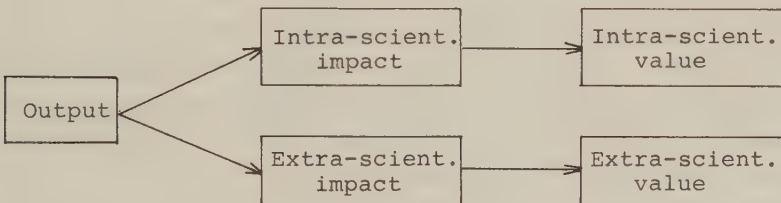
1. Introduction

By "rated performance measures" I mean here the ratings (on a scale from 1 to 5) of various aspects of research effectiveness supplied by evaluators inside and outside the research groups. These subjective measures are treated as distinct from the objective measures, i.e. quantity of output, etc.

The main question asked here is whether or not the rated performance measures contribute useful information in addition to that contained in the output measures.

2. The theoretical framework

The general philosophy underlying the present treatment of performance measures is that the effectiveness of research can be measured in two main dimensions (intra-scientific v. extra-scientific) each involving three levels: output, impact and value. The model and the main interactions among its elements are given below:



In the model, it is assumed that "value" presupposes "impact", and "impact" presupposes "output". By impact I mean the reaction or change of/in some social system caused by a given research output. By value I mean the assessment of the impact in terms of some specified set of value criteria.

One could state generally that the degree of difficulty in obtaining reliable and valid information increases as we move from "output" through "impact" to "value". The crucial methodological question is then: how much information about "value" can be derived from the information on "impact" and about both from the information on "output"? Conversely we can ask: how much useful information can we gain by adding to what we know about output the results of a given impact and/or value measurement?

Theoretically one can assume that the answers to the above questions will differ depending on which of the two dimensions (intra-scientific or extra-scientific social) we are considering. It is reasonable to expect that there is a fairly high correlation between the three levels of measurement in the intra-scientific dimension. For instance, a piece of research which strongly affects the development in its field is likely to have high scientific value. The same cannot be said about the extra-scientific impacts which may have either positive or negative values. In other words, the measurement of the scientific value can be largely replaced by the measures of output and impact, whereas the measurement of the social value cannot be so replaced.

In addition, the science system can be viewed as relatively well integrated and therefore homogenous from the point of view of the value criteria. The larger social system, on the other hand, is more heterogenous and involves a multiplicity of different and often conflicting value criteria. Consequently, one would expect that the measurement of research effectiveness in the social dimension will pose a much greater problem than that in the intra-scientific dimension.

3. The data

The impact and value aspects of research performance of the groups included in our study were assessed with the help of questionnaires administered to three groups of respondents: the heads of the groups (SA), the other scientists in the group (SB) and the external evaluators (EV). At the end of this appendix the reader will find the full text of these questionnaires. As can be seen in Table C1 there is a complete overlap between the SA and SB questionnaires. The questions about international reputation and the demand for publications were not put to the EVs.

Table C1 Contents of the three questionnaires (SA, SB, EV)

<u>Item</u>	<u>SA</u>	<u>SB</u>	<u>EV</u>
1. Productiveness	x	x	x
2. Innovativeness	x	x	x
3. Effectiveness (org)	x	x	x
4. Training effect	x	x	x
5. Non R&D effect	x	x	x
6. International reputation	x	x	
7. Demand for publications	x	x	
8. Social value	x	x	x
9. Usefulness	x	x	x
10. Quality	x	x	x
11. Adm effect: schedules	x	x	x
12. Adm effect: budget	x	x	x
13. General contribution	x	x	x

Since the SB and EV responses for each group were aggregated to form a single variable for each, we have at our disposal 37 raw rated performance measures.

There are four sets of questions that must be asked about those 37 measures:

- 1) how much information do they contain?
- 2) is that information reliable?
- 3) is it valid?, and
- 4) can it be conveniently and meaningfully summarized?

4. Missing data and distributional tests of the measures

First of all we must inquire about the missing data rates of the individual variables. Table C2 gives the percentages of missing data on the respondent and group level for the three categories of evaluators. Note that for SAs the group and respondent levels are identical, hence a single column.

It will be seen that the MD rates stay at a reasonable level for most items. The important exceptions are the items "Social value" and "Usefulness". In the first case, between 46 and 60 percent of the respondents could not provide information. In the second case, the figures are also high: between 32 and 40 percent. Unless we are prepared to treat missing data as a special sort of information, one must conclude that we are in a rather weak position as far as the measurement of the social effectiveness of the groups is concerned. That result, however, is not surprising considering the fact that most groups in our sample are oriented towards fundamental rather than applied research.

It may also be observed that there are very high missing data rates for the EV items related to administrative effectiveness. This is not surprising since the external evaluators will generally have little knowledge of such matters.

Another simple statistical test of our measures has to do with their distributional properties. For the kind of scales used here, it is general practice to set the following limit values: standard deviation should be at least .7 and the skew not more than 2. Applying these criteria to the measures on the group

Table C2 Missing data rates (percentage)

<u>Item</u>	<u>SA</u>	<u>SB</u>		<u>EV^{1/}</u>	
		<u>Resp.</u>	<u>Group</u>	<u>Resp.</u>	<u>Group</u>
1. Productiveness	3	7	4	1	14
2. Innovativeness	8	11	6	1	14
3. Effectiveness (org)	6	12	4	13	15
4. Training effect.	3	10	4	20	18
5. Non R&D effect.	12	17	7	36	16
6. International rep.	8	17	5	--	--
7. Demand for publ.	12	20	8	--	--
8. Social value	60	60	41	46	32
9. Usefulness	38	32	14	40	30
10. Quality	18	16	8	8	14
11. Adm. effect: schedules	19	19	8	49	25
12. Adm. effect: budget	16	13	8	60	36
13. General contribution	18	13	4	1	14

Note 1/: The "group" column for EVs may have higher values than the respondent column since there were several groups for which we were not able to obtain any external evaluators. The number of groups with a given number of external evaluators who supplied information is given in Table C3.

Table C3 The number of EVs per group

<u>Number of evaluators</u>	<u>% of groups</u>
0	13
1	14
2	19
3	29
4	16
5-	9

level, we find that all of them are acceptable. The skews are moderate: generally about .5. The standard deviations tend to be around 0.8-0.9. However, there is a marked difference between SAs and SBs on one hand, and the EVs on the other: the EV items tend to have standard deviations of around 0.75.

We can thus say that the 37 variables at our disposal have good or moderately good distributional properties but some of them have an unacceptably high level of missing data.

5. Item-reliability test through the analysis of variance

A measurement instrument is reliable to the extent to which the measurements it produces are stable on repetition. Each of our questionnaire items can be regarded as a measuring instrument. In as much as most of the items (SB and EV items) were used by two or more persons assessing the same property of the same group, we are in a position to give a rough estimate of their reliability. (Actually, what I am proposing to do is to test the reliability of the questionnaire item plus the type of respondent: SB or EV).

One can assess the item-respondent reliability by asking two related questions: how much of the total variation of the individual responses to a given item is due to the difference between the groups judged and how much of it is due to the differences between the judges themselves?; and: Are the differences in the group means for a given item significant?

Clearly, if the differences between the evaluators judging a given group are so great that the differences between the group means (the averages of the individual ratings) are not significant, our variables should be dismissed as unreliable.

In order to answer these questions a one-way analysis of variance of each of the SB and EV questionnaire items was carried out. Tables C4 and C5 give: a) ETA^2 which is the percentage of the between groups variation over the total variation of the

item, b) adjusted ETA^2 , which is ETA^2 adjusted for the degrees of freedom, and c) the significance level of the mean (F-test).

The results obtained are both interesting and useful. First of all it appears that almost all the group means are significant. In fact 20 out of 24 means are significant on 1% level or better. The percentage of the explained variance (ETA^2) in our data varies between 70 and 41 which, considering the nature of our measurements, is satisfactory. The relative confidence in the individual items can be best estimated from the adjusted ETA^2 s. The following observations can be made:

The SB items tend to be more reliable than the EV items. The average adjusted ETA^2 for SB is .29, whereas for EV it is .19.

It is interesting to observe that the three SB items that have the highest adjusted ETA^2 s (Usefulness .48, Demand for publications .44, and International reputation .42) are all related to the impact level of measurement. They are clearly better than the more general items such as Productiveness, Innovativeness or General contribution. This I believe is an important finding. The scientists seem to agree among themselves concerning the reaction of the environment to the performance of the group. The corresponding variables are likely to be the most promising in the entire set.

There are no great differences in the reliabilities of the EV items. The surprisingly high reliability of the item Adm effect: Budget, may depend on the fact that the few respondents (40%) who answered the question might have been particularly well informed about the situation in the group.

On the average (considering the SB and EV items simultaneously), the least satisfactory item is "Social value". The group mean is barely significant for SBs and is not significant for EVs.

Concerning the SA data, which could not be subjected to the analysis of variance, one can assume that it has at least as good reliabilities as the SB data. However, the latter benefits from

Table C4 Analysis of variance - 58 items

<u>Items</u>	<u>ETA²</u>	<u>adj.ETA²</u>	<u>Significance</u>
1. Productiveness	.51	.18	.01
2. Innovativeness	.52	.18	.01
3. Effectiveness (org.)	.56	.25	.005
4. Training effectiveness	.57	.29	.005
5. Non R&D effectiveness	.58	.29	.005
6. International rep.	.68	.42	.005
7. Publ. demand	.67	.44	.005
8. Social value	.56	.21	.05
9. Usefulness	.70	.48	.005
10. Quality	.54	.25	.01
11. Adm.effect.: schedules	.58	.27	.005
12. Adm.effect.: budget	.58	.29	.005
13. General contribution	.52	.19	.01

Table C5 Analysis of variance - EV items

<u>Items</u>	<u>ETA²</u>	<u>adj.ETA²</u>	<u>Significance</u>
1. Productiveness	.42	.18	.01
2. Innovativeness	.43	.18	.005
3. Effectiveness (org.)	.47	.20	.005
4. Training effectiveness	.45	.16	.05
5. Non R&D effect.	.54	.14	.05
6. Social value	.49	.21	.01
7. Usefulness	.51	.22	.01
8. Quality	.41	.18	.05
9. Adm.effect.: schedules	.47	.10	not sign.
10. Adm.effect.: budget	.63	.36	.01
11. General contribution	.44	.20	.005

cancellation of random error when it is aggregated, and therefore is likely to be more reliable on the group level.

The analysis of variance tests leads to the conclusion that several of the 37 raw performance measures contain sufficient amounts of reliable information to be used as materials for the index construction. However, before we can commit ourselves to those indices, we have to assess their validity. The process of validating the index measures can be split into two stages: i) correlational analysis of the raw variables, and ii) construction of validity tests for the indices.

6. The clustering patterns among the rated performance measures

On purely logical grounds, one would expect the following patterns of clustering among the performance measures:

- 1) Research performance cluster consisting of:
 - Productiveness
 - Innovativeness
 - Quality
 - General contribution
- 2) Scientific recognition cluster consisting of:
 - International reputation
 - Demand for publications
- 3) Organizational R&D effectiveness cluster consisting of:
 - Effectiveness (org.)
 - Training effectiveness
- 4) Social usefulness cluster consisting of:
 - Social value
 - Usefulness
- 5) Administrative effectiveness cluster consisting of:
 - Schedules
 - Budget

The item "Non R&D effectiveness" is difficult to allocate and is likely to stand on its own.

The above clusters are likely to be intercorrelated. One would expect the closest relation between the Research Performance cluster and the Scientific Recognition cluster.

Along with the logical connections among the items, one should consider the psychological ones. First of all, due to the respondent bias, the correlations within and between clusters should be the greatest within each separate respondent category. The random error and the differences in bias will weaken the strength of correlations between the categories. Secondly, due to the differences in the level of information, one can expect that the response pattern of EVs will be less differentiated than those of SAs or SBs. That will have an additional "bias" effect on the EV data which will further weaken its correlations with the other two sets.

The correlation patterns for the items in each respondent category were assessed using a multidimensional scaling technique (Mdscale/OSIRIS). Solutions in up to four dimensions were sought. For the EV data a fully satisfactory solution was found in two dimensions. For the SA and SB sets, three dimensions were needed. That verifies the assumption that the EV response pattern would be less differentiated than the SA and SB patterns.

Diagrams 1, 2 and 3 show the two dimensional solutions for each of the three variable sets. The solutions are suboptimal for the SA and SB sets but are given here since they are easier to interpret visually than the complete three dimensional solutions. Note: the closer the variables on the diagram, the more inter-related they are.

It will be seen from the diagrams that the above postulated cluster of items actually appear in the data. The best cluster matching obtains in the case of the following subsets of variables:

Diagram 1: The spatial arrangement (MDSCAL) of SA items

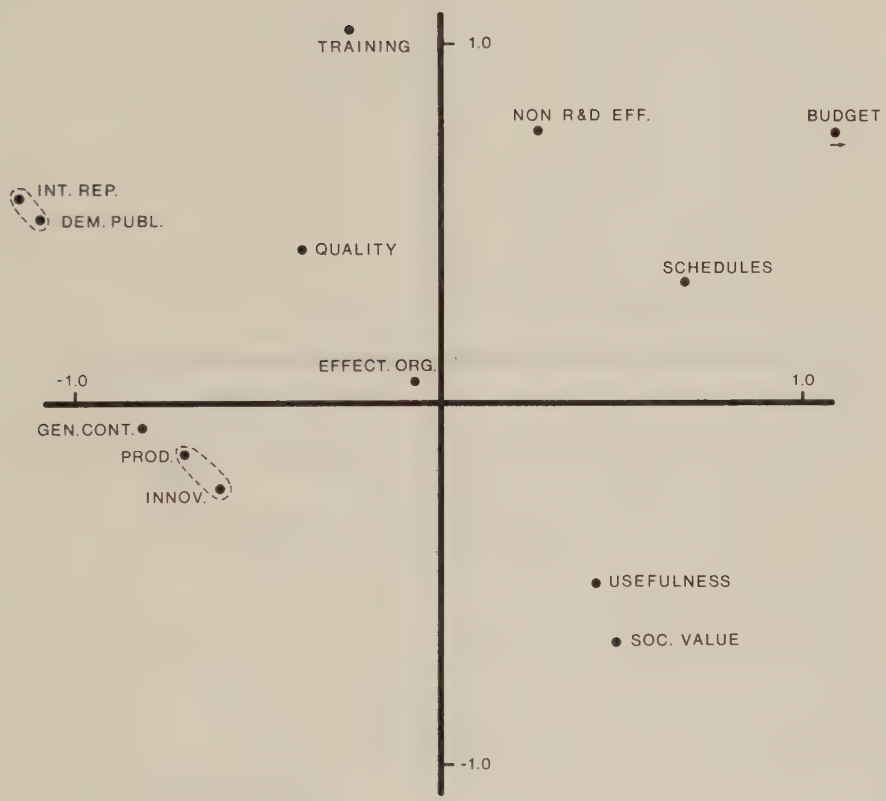


Diagram 2: The spatial arrangement (MDSCAL) of SB items

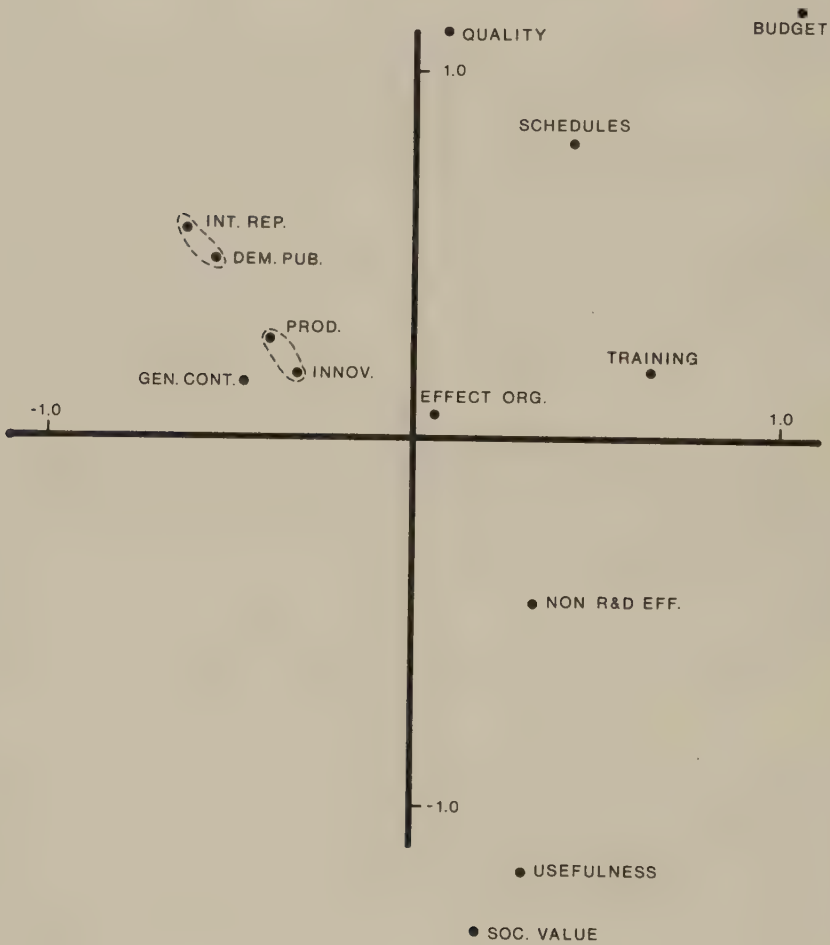


Diagram 3: The spatial arrangement (MDSCAL) of EV items



- Internal reputation and Demand for publications
- Productiveness, Innovativeness, and General contribution
- Usefulness, and Social value
- Schedule and Budget

The remaining items tend to change positions depending on the type of respondent.

The diagrams are interesting also because they show that the three aspects of research performance, scientific value, social value and administrative effectiveness appear to be largely unrelated to one another.

Note also that most of the EV items cluster along a single dimension (vertical axis).

What about the correlations between the items across the respondent categories? Given the original item reliability estimates, we would expect those correlations to be very low indeed. For example: the lower limit estimate for the SB-EV correlation on General Contribution would be the square root of .19 times .20, which equals .195. (That assumes that the reduction of correlation is due solely to the random error). The observed correlation is .22, which indicates a reduction of error due to the aggregation of the individual SB and EV values respectively.

Table C6 gives the item-to-item correlations across the three respondent categories. Table C7 gives the correlations of the EV items with the SA and SB scientific recognition variables (International Rep and Demand for Publications).

As the figures show, the correlations are low as predicted. Once again we can see that the impact items (Int rep, Demand f Publ, and Usefulness) are the best. The EV items cross-correlate very poorly. However, they correlate relatively better when they are related to the Int Rep, and Demand f Publ items, particularly from the SB set (Table C7). That again increases our confidence in the impact measures.

Given the low inter-item correlations and the original reliability scores, it is fairly obvious that none of our original raw variables is sufficiently good to be used as a performance measure in its own right.

Table C6 Item-to-item correlations across respondent categories

	<u>SA-SB</u>	<u>SA-EV</u>	<u>SB-EV</u>
Productiveness	.30	.18	.27
Innovativeness	.29	.22	.15
Effectiveness (org)	.21	.07	.23
Training effect.	.26	.19	.13
Non R&D effect.	.24	.01	.18
International rep.	.55	---	---
Demand for publ.	.45	---	---
Social value	.34	.31	-.04
Usefulness	.56	.25	.26
Quality	.23	.15	.21
Adm.effect.: Schedules	.39	.19	.21
Adm.effect.: Budget	.40	.15	.12
General contribution	.36	.22	.22

Table C7 Relationship between Int.Rep and Dem.f.Publ. items
in SA and SB and the EV items

	<u>SA</u>		<u>SB</u>	
	<u>IR</u>	<u>DP</u>	<u>IR</u>	<u>DP</u>
Productiveness	.29	.10	.36	.33
Innovativeness	.25	.12	.31	.29
Effectiveness (org)	.22	.05	.30	.27
Training effect.	.21	-.03	.24	.15
Non R&D effect.	.07	-.09	.17	.17
Social value	-.04	-.18	.02	.09
Quality	.28	.17	.24	.20
Adm.effect.: Schedules	.17	.05	.23	.14
Adm.effect.: Budget	.04	.01	-.02	-.07
General contribution	.35	.18	.38	.30

For this reason, a set of indices has been constructed and subjected to a construct-validity test.

7. The construct validity test

A construct validity test for the entire international data set has been conducted at Unesco in Paris. Since the correlation patterns in the Swedish data closely resembled those in the total international population, we considered it superfluous to repeat the analysis on the Swedish data alone. For further details see Andrews, ed. (1979).

The purpose of the test was to decompose the total variance of each proposed measure into three components: i) the valid variance, ii) the bias variance (correlated error), and iii) the residual variance (uncorrelated error). The approach used was that of fitting a structural model with specified factors and constrained parameters. The calculations were done using LISREL program (Joreskog & Van Thillo, 1972).

The full form of the tested model is given in Exhibit 1. (All the exhibits in this section are reproduced from the Unesco report). The rectangular boxes represent the measured variables. As can be seen, those correspond to the aggregations of the SA, SB and EV items. The last two of them (Application effectiveness) are additional items taken from other parts of SA and SB questionnaires and will not be considered in our discussion. The circles represent the factors. The factors to the left are called performance factors and are allowed to be correlated. The factors to the right are bias factors, one for each respondent category. They are given as orthogonal to each other and to the performance factors. In addition, the loadings of each of the bias factors are constrained to be constant.

Three versions of the model were tested: i) full form, ii) full form minus EV items, and iii) full form minus bias factors. An excellent fit is obtained when the second form is tested. The first form is almost as good, while the third is clearly inferior to the first two.

Exhibit 2 gives the estimated validity and bias coefficient for the individual measures in each form of the model. As can be seen, the best validities are found among the SB items, and the lowest among the EV items. Among the measurements, the best validity is found for the Recognition indices.

Exhibit 3 gives the observed and "true" (estimated) correlations between performance factors. The correlations are roughly what could be expected from the correlation patterns among the raw scores or on purely theoretical grounds.

Exhibit 4 is of particular interest. It shows the validity and bias coefficients of the measures when they are calculated for each respondent category separately and for the combinations SA + SB and SA + SB + EV. There appears to be a clear gain in validity when the SA and SB items are combined. The improvement is only marginal when the EV items are added.

Exhibit 1

Full form of measurement model

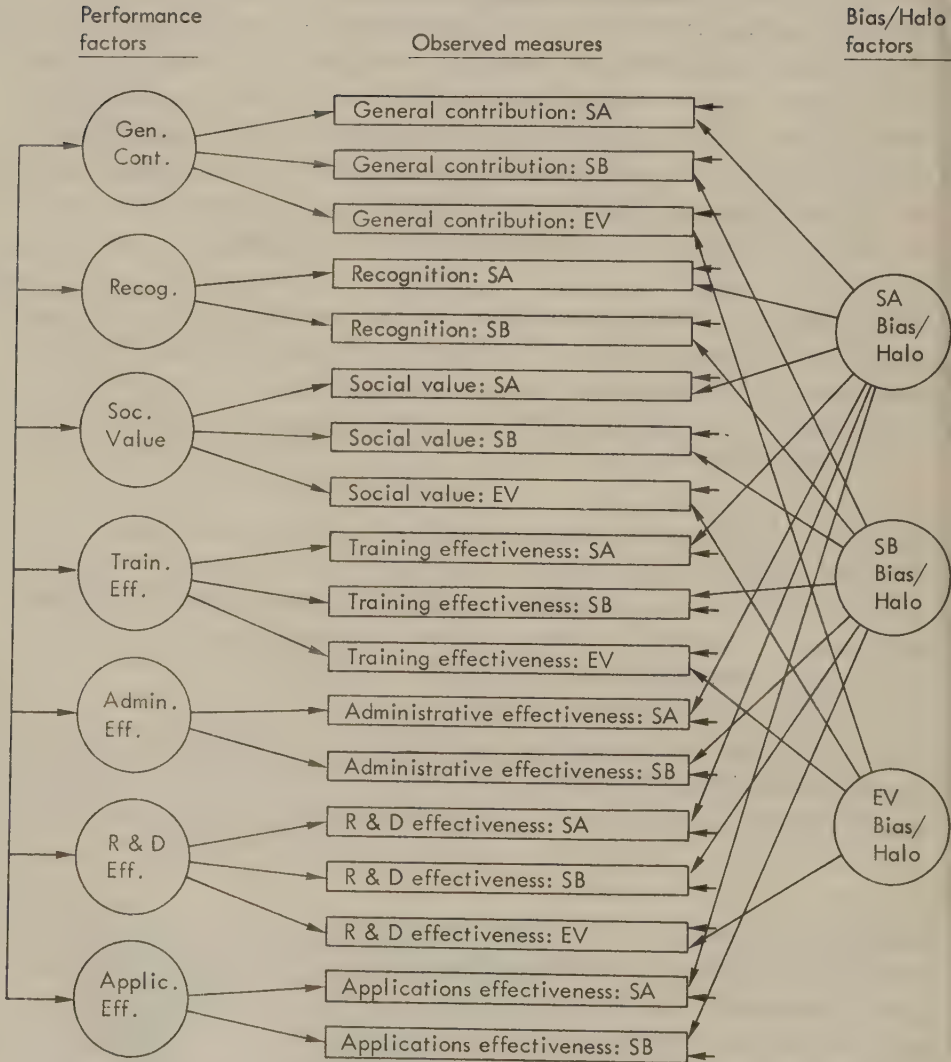


Exhibit 2

Coefficients of construct validity and bias/halo effect as estimated by three forms of the measurement model

Model form:	Form 1		Form 2		Form 3	
	(full model)		(EV omitted)		(no bias.EV)	
Rater:	<u>SA</u>	<u>SB</u>	<u>EV</u>	<u>SA</u>	<u>SB</u>	<u>SB</u>
Validity coefficients:						
General contribution	.57	.63	.38	.59	.65	.67
Recognition	.71	.76	a	.70	.75	.76
Social value	.60	.72	.54	.60	.73	.75
Training effectiveness	.58	.58	.41	.59	.55	.58
Administrative effect.	.51	.56	a	.47	.59	.58
R&D effectiveness	.57	.67	.37	.59	.67	.66
Application effect.	.63	.69	a	.62	.71	.78
MEDIAN VALIDITY	.58	.67	.40	.59	.67	.67
Bias/halo effects:	.43	.41	.72	.43	.42	b

a This aspect of effectiveness not rated by external evaluators

b Bias/halo factors were not included in Form 3 of the model

Exhibit 3

Relationships among aspects of performance

Upper figure: linkages among "true" variables^a

Lower figure: correlations among observed measures (SA, SB, EV combined)

	<u>Gen. Cont.</u>	<u>Recog.</u>	<u>Soc. Val.</u>	<u>Trng. eff.</u>	<u>Admin. eff.</u>	<u>R&D eff.</u>
Recognition	.67 .55					
Social value	.39 .32	-.01 .09				
Training eff.	.26 .30	.32 .35	-.05 .09			
Admin.eff.	.29 .25	.07 .15	.10 .19	.08 .12		
R & D eff.	.83 .67	.49 .44	.30 .29	.31 .33	.30 .21	
Applic.eff.	.03 .12	-.22 -.06	.29 .32	-.32 .33	-.10 .08	.43 .33

^a Results from Form 2 of the model

Exhibit 4

Estimated construct validity for individual and various composite performance measures

	<u>SA</u>	<u>SB</u>	<u>EV</u>	<u>SA+SB</u>	<u>SA+SB+EV</u>
Validity coefficients:					
General contribution	.57	.63	.38	.73	.76
Recognition	.71	.76	a	.84	.84 ^b
Social value	.60	.72	.54	.77	.81
Training effectiveness	.58	.58	.41	.71	.72
Administrative effect.	.51	.56	a	.66	.66 ^b
R&D effectiveness	.57	.67	.37	.75	.76
Application effect.	.63	.69	a	.77	.77 ^b
MEDIAN VALIDITY	.58	.67	.40	.75	.76
Bias/halo effects:					
SA bias/halo	.43	-	-	.26	.20
SE bias/halo	-	.41	-	.25	.19
EV bias/halo	-	-	.72	-	.33

a This aspect of performance not rated by external evaluators

b This value repeated from SA+SB combination; no separate EV data exists

The conclusion from the construct validity test is that, while our measures are far from perfect, they do represent quite usable performance estimates. A typical SA + SB + EV measure contains 58% valid variance, 7% SA bias, 6% SB bias, 11% EV bias, and 25% residual variance. The best of our measures (scientific recognition) is estimated to contain 71% valid variance. The worst measure (Administrative Effectiveness) is estimated to contain 44% valid variance.

Since the validity of the quantitative output as the measure of performance can be estimated to be somewhat between .60 and .70 (Cole & Cole, 1973), it seems quite likely that combining it in analysis with our rated performance measures (especially that of Recognition) should result in high validity and reliability of results.

8. Conclusions

The most general conclusion emerging from the analysis of the 37 raw rated performance measures is that they constitute a useful information pool for the analysis of most of the aspects of research performance of the group studied. However, in order to achieve reasonable levels of reliability and validity, the raw ratings must be combined to form a smaller set of indices.

The best indices can be formed to measure the intra-scientific aspect of performance. The measurement of the extra-scientific (social) aspect is problematic partly because of the high missing data rates and partly due to the unreliability of the raw measures (especially Social value).

Among the intra-scientific performance measures the best reliability and validity coefficients relate to the Scientific Recognition index. This fact is of great importance since one would expect, especially in academic science, that research performance is highly correlated with the scientific recognition.

PART II: Presentation of the output measures

Research results can be communicated in a variety of forms ranging from books to prototypes. A full description of the output of a research group requires that we take all such forms into account. In our study, we have inquired about 13 specified types of output. In addition, we have included two residual categories "other written output", and "other undocumented output". Table C8 lists the outputs on which we have obtained information.

The listed outputs can be classified in a number of ways. First of all, we distinguish between:

1. Written output including books, articles, restricted reports, etc., and
2. Non-written ("undocumented") outputs such as prototype devices, materials, etc.

Another classification could be made on the basis of the degree of "finality" where we could distinguish between the "end-products" such as published papers, patents, books, and the "intermediate products" such as internal and routine reports. Still another distinction which could be made is that between primary and secondary information. While articles typically carry the results of new investigations, reviews and books often sum up previously published information.

Clearly, the measurement of research output involves many dimensions. This complexity poses a serious problem for our analysis; one should like to avoid working with dozens of dependent variables. There are two ways of overcoming this problem: one can either attempt to reduce the complexity in the data by forming a smaller set of indices, or one may check whether some of the variables could not be omitted.

Originally the International Research Team collectively adopted the first strategy.

While it simplifies the analysis, the creation of indices poses some problems of interpretation. Certain subtle but important distinctions in the patterns of research performance may be lost. For example: should one combine books (which often represent "secondary" rather than original publication) with articles merely because they are correlated? And what would be the appropriate method for weighting such two different components of an index?

It would therefore seem advisable to investigate first the merits of each of the output measures taken separately and only then decide about the possible indices. We shall start therefore by asking which of the output measures could be eliminated from further analysis. I should like to propose three criteria for judging the measures:

- a) The relative frequency with which the outputs are reported. The outputs which occur only rarely (the frequency less than, say, 20%) are difficult to handle statistically even if we dichotomize them. They simply have too low a degree of variation.
- b) The relationship to the rated performance measures. The outputs which show no relationship to the qualitative ratings are of less interest than those which do. This is implied in our general model for measuring the research performance in which we view the quantitative and qualitative measures as linked variables. The analysis may also indicate which of the output variables are redundant.
- c) The theoretical considerations. Some outputs, such as articles, or patents, have greater intrinsic interest than, say, "audiovisual materials" or "routine reports".

Let us consider the output measures from the point of view of the first of the above criteria: the distributional properties.

Table C8 Types of output: distributional properties and
% of groups reporting given output

Type of output	Median	Mean	s.d.	Skewness	% reporting
Books	0.13	0.73	3.07	8.86	19.7
Articles: Sweden	1.32	4.13	7.20	3.24	55.9
Articles: abroad	3.08	6.54	9.33	2.57	67.4
Patents: Sweden	0.05	0.20	0.86	5.56	8.1
Patents: abroad	0.01	0.22	1.98	11.31	2.3
Algorithms, etc.	0.05	0.44	2.03	6.12	7.6
Reviews, bibliogr.	0.15	0.60	1.97	6.85	22.2
Internal reports	0.61	4.02	8.23	3.97	48.3
Routine reports	0.22	2.24	5.71	4.00	27.3
Other written	0.13	1.77	8.01	8.33	18.7
Prototype: devices	0.12	0.76	2.67	5.27	16.3
Prototype: materials	0.08	0.45	1.77	5.87	10.6
Prototype: com.prog.	0.38	3.99	11.06	4.96	36.7
Audio-visual mat.	0.04	0.76	6.68	11.35	5.9
Total articles	5.50	10.20	14.34	3.14	82.6

Table C8 presents the univariate statistics for the output measures in the Swedish sub-sample. The last column to the right gives the percentages of groups reporting at least some output of a given type. As it can be seen all the variables show strong, often extremely strong, skews. Only two outputs occur with a frequency greater than 50%; these are "Articles: Sweden" and "Articles: abroad". "Internal reports" and "Prototype computer programmes" occur also fairly frequently. Not less than 9 of the listed outputs have the frequency of occurrence less than 20%. Patens, for instance, are reported by less than 10% of groups.

On the basis of table C8 I selected a smaller set of variables which appeared to be potentially useful as output measures. These were: Articles Published Abroad, Articles Published in Sweden, Internal Reports, Prototype Computer Programmes, Rou-

tine Reports, Reviews, Books and Prototype Devices. Of these the first three appeared to be clearly superior in terms of distributional properties.

The next step in the analysis was to relate the above listed measures of output to the qualitative performance ratings discussed in Part I of this appendix. The examination of the qualitative performance ratings led to the identification of one cluster of variables which appeared to be superior to the others (with the possible exception of usefulness) in terms of relevance, reliability and validity. These variables measured the group members' perception of the group's International Reputation and of the Demand for Group's Publications. The index of Scientific Recognition based on these variables must, therefore, be considered as the most appropriate qualitative measure of the groups' effectiveness. The question then is: what is the correlation between the various output measures and the index of recognition? On the basis of earlier studies such as those performed by (Cole & Cole, 1973) we would expect the qualitative and quantitative measures of performance to be intercorrelated at approximately .6 level. Consequently the presence of such correlation might be regarded as an indicator of validity of the measures. Table C9 indicates the fraction of the variance of the index of Scientific Recognition which can be explained in terms of various output variables and their combinations. For the sake of comparison the table gives also the figures for the index of Usefulness -- another qualitative index with high reliability. It is quite plain that Scientific Recognition is correlated strongly (beta around .6) with the output of papers. The remaining measures are either irrelevant or redundant. The index of Usefulness is clearly less related to the measures of output; yet here again we see significant correlations with the output of published papers and with the internal and routine reports.

The overall conclusion to be drawn from the above analysis is that the output of published papers alone appears to be a quite adequate measure of the quantity of output produced by the groups, at least as far as their intra-scientific performance

is concerned. Should we be interested in the applied value of the work done by the groups, the output of routine reports and internal reports might also be considered.

Table C9 The relations between the indices of "Scientific Recognition" and "Usefulness" and selected output measures (ANOVA + MCA approach)

Output	"Scientific Recognition"		"Usefulness"	
	adj.ETA ²	evaluation	adj.ETA ²	evaluation
Books	.05	R	.03	R
Articles: Sweden	.11	+	.11	+
Articles: abroad	.32	+	.12	+
Reviews	.04	R	.00	0
Internal Reports	.01	0	.08	+
Routine Reports	.00	0	.04	+
Prototype devices	.03	R	.06	R
Prototype programmes	.03	R	.02	R

Articles Sweden & Articles abroad	.37		.14	
Internal Reports & Routine Reports	.01		.17	

Note: + significant brutto and marginal effects
 R no significant marginal effects (redundant)
 0 no significant relationship

T. VALUE OF THE WORK OF THE RESEARCH UNIT

Please indicate, for each of the following pairs of extreme statements, the column which most accurately describes your views about the value of the work of the research unit covering the **LAST THREE YEARS** by selecting ONE number for each pair of statements below and writing it in the space provided. Since this questionnaire is used in a variety of organizational settings, some questions may be irrelevant to certain individual units

Caution: Please avoid leaving blanks by writing in the space provided "NA" if not applicable or "UN" if unable to reply

X	X applies	Tend. to X	Intermediate	Tend. to Y	Y applies	Y
	a Productiveness					
The unit has been highly <u>productive</u> in the sense of adding knowledge, methods or inventions in its field of work	1	2	3	4	5	The unit's <u>productivity</u> has been very <u>low</u> in the sense defined
	b Innovativeness					
The unit has been highly <u>innovative</u> in generating useful new ideas, approaches, methods, inventions or applications in its field of work	1	2	3	4	5	The unit has been very <u>uninnovative</u> in the sense described
	c Effectiveness					
The work of the unit has been extremely <u>useful</u> in helping the organization to which it belongs to carry out its responsibilities <u>with regard to:</u>	X					The work of the unit has been largely <u>ineffective</u> in furthering the objectives of the organization to which it belongs <u>with regard to:</u>
	i Research and experimental development (R&D)					
	1	2	3	4	5	
	ii Training of scientists and engineers					
	1	2	3	4	5	
	d Scientific/technical objectives other than R&D					
The work of the unit has been extremely <u>useful</u> to its Organization regarding its scientific/technical objectives other than R&D and training (e.g. consulting work, routine and control analysis and studies, scientific information and/or documentation)	1	2	3	4	5	The work of the unit has been largely <u>ineffective</u> for its Organization regarding its scientific/technical objectives other than R&D and training

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X

Y

X	X applies Tend. to X	Intermediate	Tend. to Y	Y applies	Y			
	e	Response from the scientific communities						
The unit has a high international reputation	i	1	2	3	4	5	The unit is virtually unknown abroad	6 / 64
The publications of the unit are in high demand and often cited in literature	ii	1	2	3	4	5	The publications of the unit are largely ignored	65
	f	Social value						
The social value of applications given (or which may be given) to the results of the unit's work are highly positive		1	2	3	4	5	The social value of applications given (or which may be given) to the results of the unit's work are highly negative	66
	g	Usefulness						
The work of the unit has been extremely <u>useful</u> in helping to solve some current problems facing society		1	2	3	4	5	The work of the unit has been largely <u>ineffective</u> in helping to solve some current problems facing society	67
	h	Quality of the work of the unit						
The unit has been very <u>successful</u> in meeting the quality requirements associated with its work (e.g. design, product performance, validity of results, consumer reception, presentation of findings)		1	2	3	4	5	The unit has been very <u>unsuccessful</u> in meeting the quality requirements associated with its work	68
	j	Administrative effectiveness						
The unit has been very <u>successful</u> with regard to:							The unit has been very <u>unsuccessful</u> with regard to:	
	i				Meeting its schedules			
		1	2	3	4	5		69
	ii	Staying within its operating budget						
		1	2	3	4	5		70
	k	General contribution to science or technology						
The unit has made an outstanding <u>contribution</u> to scientific or technical development in its field		1	2	3	4	5	The unit has made <u>little or no contribution</u> to scientific or technical development in its field	71

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